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EDITORIAL NOTES.

Owing to the incidence of the Easter holidays in the last week of March, we are obliged this month to go to press at an unusually early date. Consequently one or two items which should normally have been included in this number are unavoidably postponed. For this we wish to express our regrets.

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The list of fifteen candidates nominated by the Council for election to the Royal Society, published just too late to be mentioned in our March number, includes the name of only one geologist, Mr. C. S. Middlemiss, C.I.E., late of the Geological Survey of India and now Superintendent of the Mineral Survey of Kashmir. To him we tender our hearty congratulations. It will be remembered that last year no geologist received the honour of election. There is a widespread feeling that the state of affairs with regard to the number of candidates now awaiting election is in need of careful consideration by the Council of the Royal Society. In the list issued last February there are 118 names, belonging to nearly thirty distinct categories. Of these the largest number (23) belong to the medical profession; 20 to the chemists, 10 to the electrical and civil engineers, 10 to the geologists, 10 are botanists, 8 zoologists, 7 mathematicians, 7 physiologists, 2 mineralogists, 4 naval architects, 3 entomologists, and about 12 of unique scientists (including one veterinary surgeon). Many of these have been suspended for three or four years, and as only fifteen are elected annually, a large proportion stand very little chance of admission within a reasonable time, if ever. Whether the enormous importance attached by the scientific world to the Fellowship of the Royal Society is ultimately to the benefit of science in general is a matter that we do not propose to discuss; the fact remains that it is the heart's desire of all scientific men, and we would respectfully suggest to the Council that the time has now arrived when they might well consider the possibility of a substantial addition to the number of annual elections. Far be it from us to advocate any lowering of the standard; our point is that the number of those fully qualified has of late increased so greatly that many men as good as or even better than those elected a few years ago are now perforce left out in the cold, to the great discouragement of themselves and of the coming generation who have not yet reached the stage of candidature. In our opinion the Fellowship of the Royal Society should be regarded as an encouragement to future effort, as well as a reward for meritorious work in the past.

ORIGINAL ARTICLES.

On Cycles of Sedimentation in the Eocene Strata of the Anglo-Franco-Belgian Basin.

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(*Continued from p. 114.*)

III. THE EOCENE SUCCESSION IN EACH AREA.

A. The Paris "Basin".

The Eocene deposits of the Paris region group themselves naturally into six cycles :—

	Marine representatives.
Bartonian . . .	Calcaire de Ludes. Sables de Marines
Ledian (Auversian) .	Sables d'Auvers (Sables moyens or Sables de Beauchamp).
Lutetian . . .	Calcaire grossier.
Ypresian . . .	Sables de Cuise.
Landenian . .	Sables de Bracheux.
Montian . . .	Calcaire pisolitique.

The beds are predominantly marine towards the north and predominantly continental towards the south and south-east. At Verzenay,[1] near Reims, in the south-east, there is practically a complete succession of continental deposits from the Landenian to the Bartonian.

The diagram (Fig. 2, p. 147) shows in more detail the grouping adopted for the Eocene beds of the Paris region. It is adapted from the work of Leriche, and is the grouping now generally accepted on the Continent.[2]

Montian.—The Montian (Calcaire pisolitique) is now only found in a few isolated patches and seems to have been deposited in certain areas rather than over the whole Paris region. In some respects the fauna is intermediate between the Cretaceous and the Eocene. There are some curious anomalies in the situation of some of the deposits of this age, which tend to suggest localized formation in shallow lagoons left during the retreat of the Cretaceous sea.

It is simpler, for this reason, to commence the diagram with the next cycle—the Landenian.

Landenian.—The Lower or Marine Landenian consists of glauconitic sands, often argillaceous towards the base and tending to be harder in the lower part and to form beds of "tuffeau". Glauconite becomes less abundant in the higher parts. The Lower Landenian has been divided into three zones :—[3]

3. Zone of *Cyprina scutellaria.*
2. Zone of *Pholadomya Koninckı.*
1. Zone of *Cyprina Morrisi.*

[1] Leriche, "Observations sur les Terrains tertiaires des environs de Reims et d'Epernay" : *Ann.* Soc. géol. Nord, vol. xxxvi, 1907, p. 367.

[2] Compare Lemoine, *Géologie du Bassin de Paris*, 1911, p. 200.

[3] Leriche, "Sur les Horizons paléontologiques du Landénien marin du Nord de la France" : *Ann.* Soc. géol. Nord, vol. xxxii, 1903, p. 239.

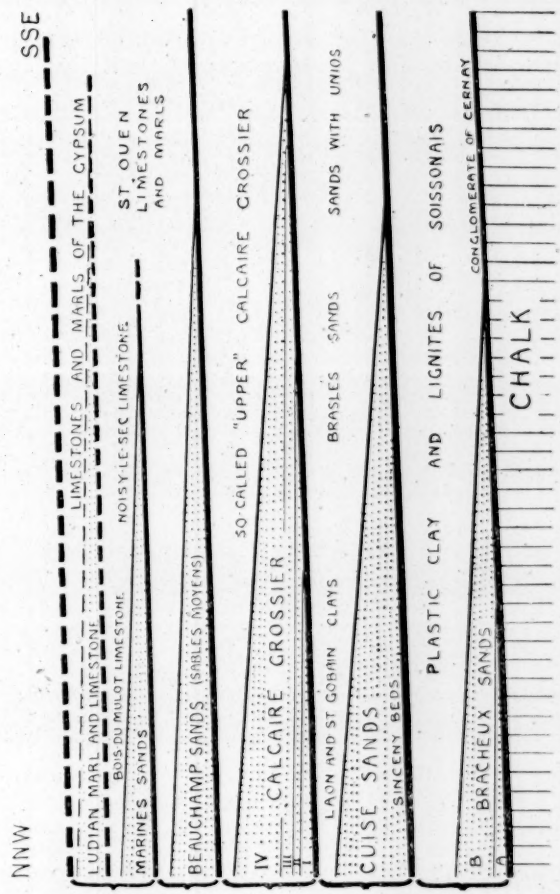


FIG. 2.—Cycles of sedimentation—Paris Basin (in part after Leriche). Landenian Zones: A = zone of *Pholadomya Koninecki*; B = zone of *Cyprina scutellaria*. Lutetian Zones: I = zone of *Maretia Omaliusi*; II = zone of *Nummulites laevigatus*; III = zone of *Ditrupa strangulata*; IV = zone of *Cerithium giganteum*.

Deposits of the earliest zone are not found in the main region of the Paris Basin, but only in North France and Belgium. The transgression continued later, so that the basal deposits in the extreme north-eastern part of the Paris Basin belong to the zone of *Pholadomya Koninecki* (Tuffeau de La Fère). The beds of the highest zone occur over a far more extensive area. In the Paris Basin they are known as the Sables de Bracheux and the Sables de Châlons-sur-Vesle. Professor Leriche has prepared a very instructive series of

maps, showing the distribution of the various marine Eocene beds in the Paris and Belgian regions;[1] and the map showing the distribution of the zones of the Landenian demonstrates very clearly the successive overstep in all directions.

The Upper Landenian (the so-called Sparnacian) marks a silting up of these shallow seas. Broad, shallow lagoons teeming with estuarine molluscs existed over a very large part of the great basin, and in them were deposited sediments of the type of our Woolwich Beds. Round them there is the broad band of lacustrine and fluviatile deposits of Reading type. The Upper Landenian was the most extensive, geographically, of all the continental episodes. The extent of marine waters in the centre of the basin must have been very small indeed. Almost the only locality now remaining where the whole of the Landenian is marine is the Isle of Thanet.

The marine Landenian has been called Thanetian on the supposition that it corresponded to the Thanet Sands of the London Basin. As Prestwich[2] and others have pointed out, the zone of *Cyprina scutellaria* is represented in England by the Bottom Bed of the Woolwich Series. The author has recently adduced further proof of this correlation.[3] The name Thanetian must therefore be dropped. It follows also that the "Sparnacian" deposits of the French do not correspond exactly to our Woolwich and Reading Beds.

Ypresian.—When one remembers the very large area covered by the shallow lagoons of Upper Landenian times, it is clear that even a slight disturbance would cause a very great change in the distribution of land and water. This question has been dealt with at some length elsewhere,[4] and it is sufficient to note here one or two of the more important conclusions. The waters of the invading Ypresian sea flooded very rapidly over the Upper Landenian lagoons. There are extensive accumulations of well-rolled flint-pebbles, and elsewhere very fine or well-washed sands, showing the disturbed conditions which prevailed at the time. For a short time the incoming marine fauna lived side by side with the existing fauna of the lagoons, and one gets the curious mixed fauna of the Sables de Sinceny. These basal Ypresian beds compare very closely with their equivalents in England—the Blackheath Beds. It is interesting to note that this distinctive fauna, associated with the peculiar type of lithology of the beds (that is beds of unbleached, well-rounded flint-pebbles), is restricted in geographical distribution to areas of pre-existing estuarine lagoons. Where the Ypresian sea invaded

[1] Leriche, *Bull.* Soc. géol. France, sér. IV, vol. xii, 1912, pls. xxiii–xxvii.

[2] Prestwich, *Quart. Journ.* Geol. Soc., vol. xliv, 1888, pp. 98–9.

[3] Stamp and Priest, "Geology of the Swanscombe Eocene Outlier": *Proc.* Geol. Assoc., vol. xxxi, 1920, p. 187.

[4] Stamp, "On the Beds at the Base of the Ypresian in the Anglo-Franco-Belgian Basin": read at the meeting of the Geologists' Association, July 2, 1920. GEOL. MAG., Vol. LVII, 1920, p. 380 (in the Press).

regions of Upper Landenian fluviatile or lacustrine beds (e.g. mottled clays) the mixed fauna of the Sables de Sinceny does not occur, and the fossils from the base of the Ypresian are entirely marine.

Apart from these basal beds the Ypresian is represented in the Paris Basin by a series of sands—the Sables de Cuise (*sensu lato*). It is characterized by the occurrence of *Nummulites planulatus* d'Orb. —*elegans* Sow.[1] The change from the disturbed conditions which prevailed during the deposition of the Sables de Sinceny to the more tranquil conditions of the Sables de Cuise is marked by the existence in many localities of a thin basal bed to the last-mentioned sands. In exactly the same way the London Clay of the London Basin retains its own basement bed even when resting on the Blackheath Beds. The Sables de Cuise are glauconitic sands, sometimes coarse, especially near the base, but on the whole remarkably fine-grained.

The Cuise Sands are succeeded by presumed continental deposits—a bed of greenish clay without fossils (Argile de Laon or de Saint Gobain), or by sands with fluviatile fossils (Sables à Unios et Térédines).

Lutetian.—The Lutetian is the famous Calcaire grossier of the Paris Basin. It generally commences with a coarse glauconitic sand, containing pebbles or rolled fossils at the base. The marine Lutetian consists of varied calcareous beds, of which the best-known is the shelly, foraminiferal limestone, so prized for building. Sandy limestones and calcareous sands are of common occurrence. Although characterized throughout by the presence of *Nummulites lævigatus* Lamk.—*Lamarcki* d'Arc., this fossil is especially abundant at one horizon. Leriche has shown that this marine Lutetian is divisible into four zones :—[2]

4. Zone of *Cerithium giganteum*.
3. Zone of *Ditrupa strangulata*.
2. Zone of *Nummulites lævigatus*.
1. Zone of *Marcia Omaliusi*.

The zone of *Nummulites lævigatus* constitutes a bed a few metres thick, consisting almost entirely of the zone-fossil. It is known as the " Pierre à liards ", and is a very easily recognized horizon. The geographical distribution of the zones demonstrates beautifully the successive overlap ; the first zone only just reaches the Paris Basin, while the higher zones have successively wider distribution.[3] The succeeding continental beds are the so-called Calcaire grossier *supérieur*, and comprise thin-bedded limestones with estuarine fossils (especially *Cerithium*). Towards the periphery of the basin these pass into unfossiliferous mottled clays and marls.

[1] In most cases the megalospheric and microspheric forms of each species of *Nummulites* have been described under different names. In this paper the double name is given on the first occasion of reference to the species, but, for the sake of brevity, the more usual name is generally used.

[2] Leriche, op. cit., 1912, p. 700 (with references).

[3] Leriche, op. cit., 1912, pl. xxv.

Ledian (*Auversian*).—The lagoon areas of the Upper Calcaire grossier were invaded by the sea, which deposited the Sables de Beauchamp. These beds are characterized by the occurrence of *Nummulites variolarius* Sow.—*Heberti* d'Arc. In the Paris Basin they generally consist of clean sands (sometimes calcareous), but appear to have been formed in shallower water than was the case with the earlier marine invasions. In places, therefore, they are more markedly false-bedded and frequently coarse. The succeeding continental deposit is a well-marked fresh-water limestone—the Calcaire de Saint Ouen—with *Limnæa* (*L. longiscata*) and *Planorbis*.

Bartonian.—When considering the highest beds of the Eocene strata in the Paris region, it is necessary to bear constantly in mind the more specialized conditions which prevailed during their formation. The marine invasion of the Ledian is very distinct, but the fauna has a shallow-water aspect. In other words the basin was becoming silted up. This is still more apparent in the succeeding stage—the Bartonian. One has all the phenomena of the partial drying-up of an enclosed sea, culminating in the deposition of enormous masses of gypsum. Interstratified with the latter one finds beds of marl with marine fossils (Ludian or Marne à *Pholadomya ludensis*). The fossils differ slightly from those found in the lower part of the stage, but the differences are such as one would expect to result from local evolution *in situ* in response to unfavourable conditions. It is not difficult to see why the highest series of the Eocene beds has been much discussed and numerous correlations proposed.

It is far better, therefore, to take as the type of the highest part of the Eocene the Hampshire sequence. There one has a perfectly natural cycle of sedimentation, commencing with the marine invasion of the Barton Clay (horizon of *Nummulites Orbignyi* Gal. —*wemmelensis* De la Harpe, = *N. prestwichianus* Rupert Jones, = *N. elegans* Sow. var. *Prestwichii* Rupert Jones), passing upwards into the shallower-water conditions of the Barton Sands (Long Mead End Beds), which, in turn, fade gradually into the continental conditions of the Lower Headon Beds. The stage is very clearly defined by the abrupt change at the base of the next marine invasion, that of the Middle Headon Beds.

Briefly, in the Paris Basin there is a lower series of marine sands—the Sables de Marines—the fauna of which differs but slightly from that of the Ledian, but in which *Nummulites variolarius* does not occur. These are succeeded by a series of marls and gypseous beds. Amongst the marls there is a thin, but constant, bed of marl or limestone—the Marne à *Pholadomya ludensis* or the Calcaire de Ludes—with marine fossils. The existence of this limestone has caused it to be said that there are two cycles in the highest Eocene of the Paris Basin, a lower or Marinesian (*sensu stricto*) and an upper or Ludian. If one examines the Calcaire de Ludes in the field, however, as at Verzenay (near the type locality of Ludes), one finds

an ill-defined band grading both upwards and downwards into fresh-water limestone. Stratigraphically, therefore, the creation of a separate stage seems unwarranted. Moreover, as Dollfus[1] has shown, there are no really new elements in the Ludian fauna, at the most some variations from the typical forms of the Sables de Marines. It is important to note, however, that both Dollfus[2] and Leriche[3] wish to include our Middle and Upper Headon Beds with the Eocene as part of the Bartonian (Leriche) = Marinesian of Dollfus.

Now there is absolutely no doubt that the Bartonian Cycle closes with the Lower Headon. The Middle Headon Beds (including the Brockenhurst Beds) commence a fresh cycle. The classification of the French beds must depend on the age assigned to the Middle Headon Beds. At present the author is strongly inclined to agree with Boussac[4] that the Middle Headon Beds mark the base of the Oligocene, and that the Ludian is exactly equivalent to the Barton Sands (Long Mead End Beds). This agrees with the old opinion of von Koenen,[5] and with the more recent opinion of White,[6] that the lowest zone of the Middle Headon (Brockenhurst Zone) contains the most clearly marine fauna in the British Oligocene. The correlation therefore stands thus:—

		Paris Basin.	*Hampshire.*
Oligocene . . .		Marls above the Gypsum.	Middle Headon Beds (including Brockenhurst Beds).
Eocene—Bartonian	Ludian . .	Ludian marls with gypsum	Lower Headon Beds and Barton Sands
	Bartonian (*sensu stricto*)	Sands of Marines and Cresne	Barton Clay.

It is only fair to state the other possible classification is as follows:—

[1] Dollfus, "Excursion to Paris": *Proc.* Geol. Assoc., vol. xxi, 1909, p. 12. The writer is indebted to M. Dollfus for further unpublished information on this question.

[2] Dollfus, "On the Classification of the Beds of the Paris Basin": *Proc.* Geol. Assoc., vol. xxi, 1909, pp. 107–12.

[3] Leriche, "Observations sur la Classification des Assises paléocènes et éocènes du Bassin de Paris": *Ann.* Soc. géol. Nord, vol. xxxiv, 1905, p. 391.

[4] Boussac, "La Limite de l'Eocène et de l'Oligocène": *Bull.* Soc. géol. France, sér. iv, vol. vii, 1907, p. 400.

[5] Von Koenen, "Ueber diie Parallelisrung des norddeutschen, englischen, und französischen Oligocäns": Zeitsch. d. deutsch. geol. Gesells., 1867, pp. 23–32.

[6] White, *Geology of the Country near Lymington and Portsmouth* (Mem. Geol. Surv.), 1915, p. 43. More recently White has adopted the correlation of Dollfuss (1909), *Handb. Reg. Geol.*, Band iii, i Abt.: The British Isles, p. 272 (1917).

		Paris Basin.	*Hampshire.*
Oligocene		Marls above the Gypsum.	Bembridge and Hamstead Beds.
Eocene—Bartonian	Ludian	Limestone and marls of the gypsum with *Phol. ludensis.*	Upper Headon Beds and Middle Headon Beds.
	Bartonian (*sensu stricto*)	Limestone of Noisy-le-Sec, etc.	Lower Headon Beds.
		Sands of Marines and Cresne.	Barton Sands.
			Barton Clay.

It seems unwarrantable to use the much misused term Bartonian to include also all the Headon Beds as Leriche [1] has done. Those who insist on grouping all these beds together with the Barton Clay and Sands as Eocene, would do better to employ the term Marinesian of Dollfus.[2]

In any case our Lower Headon Beds must be linked with the Barton Sands as Eocene, and part of the Bartonian cycle. Also the Middle Headon Beds must be regarded as the commencement of a separate cycle.

B. The Hampshire "Basin".

The Hampshire Basin is particularly suited to the study of cycles of deposition. There are at least four continuous sections of practically the whole of the Eocene sequence in the sea-cliffs—one from Studland Bay round Bournemouth Bay to Highcliffe and Barton (Long Mead End), a second in Alum Bay at the western end of the Isle of Wight, a third in Whitecliff Bay at the eastern end of the Isle, and a fourth in Bracklesham Bay and the coast of Chichester Harbour to the north. Some of the lower beds are also seen further west, in Dorset, and further east in the outliers near Newhaven, Sussex. These sections lie approximately along a west and east line, from a predominantly continental sequence in the west to an almost completely marine one in the east. The outliers at Newhaven also are closely linked stratigraphically with those near Dieppe, on the other side of the English Channel.

The accompanying diagram (Fig. 3, p. 153) shows how naturally the Eocene deposits of the Hampshire Basin group themselves into cycles. The variations in thickness of the various beds conform to the theoretical requirements to a remarkable degree, especially when one remembers there is considerable distortion due to folding.

Landenian.—The Landenian is represented in the Hampshire Basin by a series of mottled clays and coarse, false-bedded sands of fluviatile origin (Reading Beds). In the west (Dorset and Devon [3])

[1] Leriche, op. cit., 1905, p. 391.
[2] Dollfus, op. cit., 1909, p. 107.
[3] Reid, *Quart. Journ.* Geol. Soc., vol. lii, 1896, p. 490; ibid., vol. liv, 1898, p. 234.

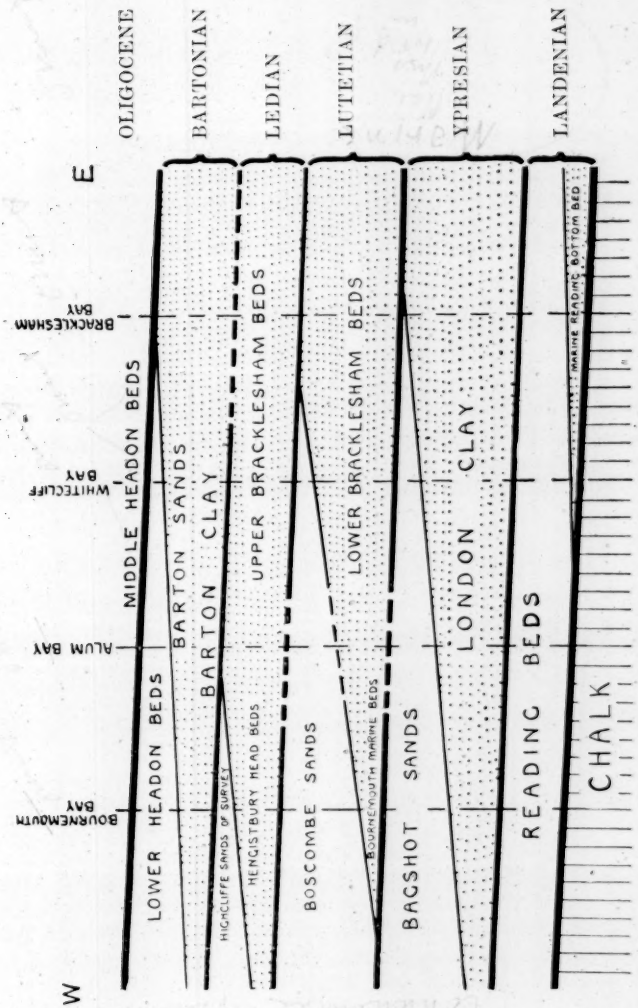


FIG. 3.—Cycles of sedimentation—Hampshire Basin.

these pass into coarse gravels, etc. In the extreme east, as at Newhaven, the mottled clays give place to well-bedded clays crowded with estuarine shells (Woolwich Beds), and similar beds occur at Dieppe. At the base of the series there is a thin bed of greenish or brownish glauconitic sand, resting on an irregular surface of Chalk. Some small rolled green-coated flints occur at the base, as well as angular flints left after the sub-surface solution of the Chalk, and the bed is obviously marine. As Parent[1] has pointed out, it is

[1] Parent, "Notes sur les Terrains Tertiaires du Pays de Caux": *Ann.* Soc. géol. Nord, vol. xxii, 1894, p. 9.

certainly a continuation of the Sables de Bracheux (zone of *Cyprina scutellaria*). This was recognized also by Prestwich. About 33 feet thick at Newhaven, it is generally hidden by slips at Whitecliff Bay, and has decreased to about 4 feet at Alum Bay. The enormous marine transgression which took place at the time of formation of the Bracheux Sands has been pointed out above. Here, in the Hampshire Basin, the evidence for the transgression is equally well marked, and also the rapid filling up of the shallow sea with fluviatile and estuarine deposits.

Ypresian.—The marine invasion of Ypresian times in England was one of the most extensive of all the Eocene invasions, yet the unconformity is very slight. As White [1] has pointed out, the estuarine and freshwater flats of late Landenian times favoured a rapid yet tranquil marine invasion. The conditions for the existence of the mixed Blackheath fauna of the London Basin did not exist in the Hampshire Basin, i.e. the brackish-water lagoon phase of the Landenian only occurs to the extreme east, at Newhaven, etc. The region was too far from the Wealden uplift to receive great masses of pebbles such as one finds in the London Basin, hence the Blackheath Beds are absent. The mass of the London Clay commences with a thin sandy pebble-bed—the Basement Bed. The London Clay itself is generally somewhat sandy, especially in the west. It thickens steadily from west to east, from 80 to 100 feet at Studland Bay, 233 feet at Alum Bay, and 320 at Whitecliff Bay, to 340 feet at Portsmouth. It includes some beds of fine sand in the upper part and passes up quite gradually into the fluviatile Bagshot Sands. As one would expect from their being continental deposits, the latter are very thick in the west, estimated at over 500 feet near Bournemouth, and they become thinner eastward, and are only about 100 feet thick in Whitecliff Bay and 30 feet at Portsmouth. To the north of Bracklesham Bay they are represented by a thin bed of sand a few feet in thickness between the marine deposits of the London Clay and Bracklesham Beds. The great mass of sands grouped under the term Bagshot Sands in the Alum Bay section undoubtedly include representatives of the Bracklesham Beds—both Lutetian and Ledian. The sands are decalcified and unfossiliferous, but it is hoped that a mineralogical examination of the sands may lead to a detection of glauconite, and indicate the marine origin of certain of the beds. The marine invasions of Lutetian and Ledian times are both very clearly seen in the Whitecliff Bay section, and are traceable as the Bournemouth Marine Series and the Hengistbury Head Beds respectively in the Bournemouth Bay section, hence they must be represented in Alum Bay.

The London Clay in the neighbourhood of Portsmouth—so ably studied by Meyer [2]—exhibits several interesting features. There

[1] White, op. cit., 1915, p. 11.

[2] Meyer, "On the Lower Tertiary Deposits recently exposed at Portsmouth": *Quart. Journ.* Geol. Soc., vol. xxvii, 1871, p. 74.

are three pebble-beds which permit of a triple division of the clay. Each division commences with a layer of pebbles, followed by stiff clay, which becomes sandy in the upper part, passing into a sand. White [1] emphasizes these variations in lithology and points out that they indicate a change from comparatively deep water to shallower-water conditions—or "shoaling"—and he actually refers to them as "cycles of deposition". At the same time White points out that these pebble-beds are constant neither in number nor in position. It is interesting to note that they increase in number as one approaches the area of the Wealden Dome, and there can be little doubt that that was the source of the pebbles, and that gentle movements of uplift during Ypresian times were responsible for the changes in lithology. It must be emphasized that these slight variations in the mass of the clay do not constitute cycles of deposition.

Lutetian.—No apology is needed for dividing the Bracklesham Beds into two divisions. Previous observers have already made this separation, and Leriche,[2] White,[3] and others have correlated the two divisions with the French succession of Lutetian and Ledian (Auversian). The first-mentioned beds are characterized by the presence of *Nummulites lævigatus*, the second by the presence of *N. variolarius*. These two species never occur together. The Lutetian invasion is marked by a basal pebble-bed or pebbly glauconitic sand at Bracklesham and Whitecliff Bays, and is very distinct. Remembering the enormous amount of sediment which was being being brought from the west and being deposited as the Bagshot Sands in the neighbourhood of Bournemouth, it is not surprising that the marine sediments of the encroaching sea should be mixed with, and partly masked by, the continental deposits. Even as far east as Whitecliff Bay one finds the basal glauconitic bed of the Lutetian succeeded by "green sand and laminated clays with seams of lignite" [4] (Fisher's Bed III), and passing further west the separation of the marine beds becomes more difficult. As mentioned above, the representatives of the marine Lutetian have not been clearly distinguished in Alum Bay. Passing across to Bournemouth Bay, the Bournemouth Marine Beds evidently mark the Lutetian marine invasion, but are at almost the western end of the sea, or, as White puts it, the beds represent "the seaward facies of a deltaic formation such as the Freshwater Series".[5]

[1] White, loc. cit., p. 11.

[2] Leriche, "Observations sur la Géologie de l'Île de Wight": *Ann.* Soc. géol. Nord, vol. xxxiv, 1905, p. 16.

[3] White, loc. cit., p. 20.

[4] Fisher, "On the Bracklesham Beds of the Isle of Wight Basin": *Quart. Journ.* Geol. Soc., vol. xviii, 1862, p. 65.

[5] White, "Geology of the Country around Bournemouth," 2nd ed. (Mem. Geol. Surv.), 1917, p. 29. The Bournemouth Freshwater Series is situated in the upper part of the Bagshot Sands.

In Bracklesham Bay the Lutetian and Ledian Series are not separated by any continental deposits, but there is a faunal break.[1] In Whitecliff Bay the marine Lutetian passes up into a succession of laminated sandy clays with lignitic seams in the upper part (Fisher's Bed VIII). The presence of underclays with rootlets in this division shows that there really was a recession of the sea towards the close of Lutetian, and that the vegetable matter was not simply drifted into these beds by marine currents. It was probably a swamp near sea-level. Near Bournemouth the break between the Lutetian and Ledian is marked by the Boscombe Sands, with their thick beds of coarse shingle. Some difference of opinion exists as to the conditions under which the Boscombe Sands were formed. The most obvious interpretation seems to the present writer to be that of subaerial shingle-banks, left by the retreating Lutetian sea. The extraordinary bleaching and alteration of the pebbles, as well as the absence of glauconite in the accompanying sands, supports this idea rather than that of submarine shoals.

Ledian.—The palæontological break between the Lutetian (Lower Bracklesham) and the Ledian (Upper Bracklesham) is a well-marked one. Not only has one the two very distinct species of *Nummulites*—*N. lævigatus* characteristic of the former and *N. variolarius* of the latter—but the whole faunas are quite distinct. There are many Ledian species which do not occur in the Lutetian but which range up into the Bartonian. As several authors have pointed out, there is a more marked palæontological break between the Lutetian and Ledian than between the Ledian and Bartonian.

The Ledian is entirely marine in both Bracklesham and Whitecliff Bays In Alum Bay there are 47 feet of glauconitic clays below the band with *Nummulites Prestwichii* (a band which is usually taken as the base of the Barton Clay). There is a strongly marked pebble-bed at the base of these clays. *Nummulites variolarius* has not been found in Alum Bay, and the present writer is uncertain whether this 47 feet of strata should be considered as representing the Ledian or whether it should be linked with the Bartonian. The Ledian seems to be represented in Bournemouth Bay by the Hengistbury Head Beds. The latter pass up into the Highcliffe Sands (of the Survey). The lower part of the latter show "wash-outs" and little seams of pipeclay, and on the whole presents a fluviatile aspect. Although in the Highcliffe section obscure casts of marine fossils are said to have been found, these sands seem to represent a feeble development of continental Ledian. Certainly the continental Ledian is very poorly developed, and the break between the Ledian and Bartonian is principally palæontological.

Bartonian.—The Bartonian cycle has already been discussed. Stratigraphically it seems likely that the base in the Highcliffe

[1] Boussac, "Observations sur la faune des couches supérieures de Bracklesham à *Nummulites variolarius*": *Ann.* Soc. géol. Nord, vol. xxxvi, 1907, p. 360.

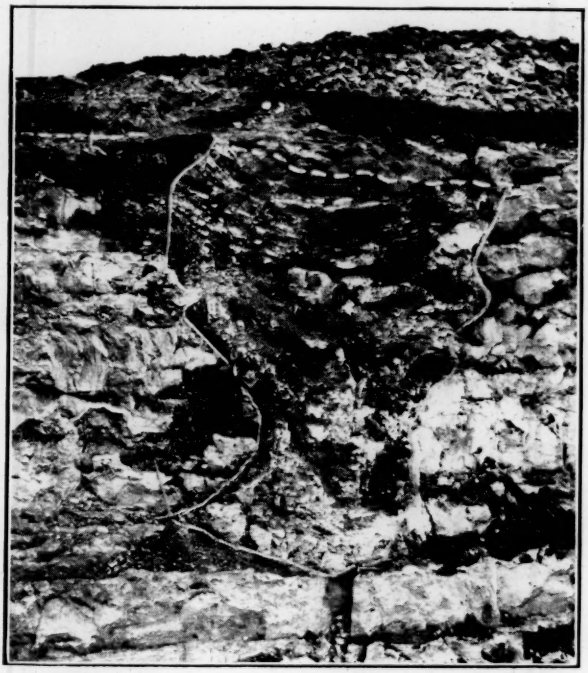


FIG. *a*.—Channel in Carboniferous Limestone, filled with sandstones and shales, the whole overlain by Trias. (Geol. Surv. Photo.)

FIG. *b*.—Carboniferous Limestone irregularly eroded, and overlain by sandstones and shales, now with a thin later covering of Trias. (Geol. Surv. Photo A 792.)

(Barton) section is the clearly defined pebble-bed towards the higher part of the Highcliffe Sands of the Survey. The glauconitic clays above this bed are strongly contrasted with the pale sands below. The *Nummulites Prestwichii* band is met with a few feet above, and so the pebble-bed and the few feet of clays between it and the Nummulite band are usually grouped in the upper part of the Bracklesham Beds. This seems curious, since the zonal Nummulite does occur, though sparingly, below its special band. Moreover, there is no lithological change at the Nummulite band, but a very obvious one at the pebble-bed below. This pebble-bed may be the same as the one seen in Alum Bay at the base of the 47 feet of doubtful beds.

The marine Bartonian beds (Barton Clay and Barton Sands) thicken steadily eastwards from 192 feet at Highcliffe (Barton) to 338 feet in Alum Bay and 368 feet in Whitecliff Bay. The first two figures are increased to 206 and 385 feet respectively if the pebble-bed is taken as the base of the Bartonian. The continental Bartonian (Lower Headon Beds) consists of freshwater limestones with *Limnæa*, marls, etc., and thins, as one would expect, from west to east; 82½ feet at Barton, from 61 to 82 feet in Alum Bay and on Headon Hill; it is reduced to 28 feet in Whitecliff Bay, and has become more estuarine.

Commencing with the Middle Headon Beds, the Oligocene deposits of the Hampshire Basin also seem to group themselves into cycles. The distribution of the zones of the Middle Headon agrees with the theory of a gradual transgression at that period, similar to the transgression observed in the Landenian or Lutetian. It is hoped to deal later with these beds.

(*To be concluded.*)

The Unconformity between the Millstone Grit and the Carboniferous Limestone at Ifton, Mon.

By E. E. L. Dixon, A.R.C.Sc., B.Sc., F.G.S.

(PLATE II)

Introduction

THE object of the present communication is to place on record a section, apparently unique, in which the unconformity between the Millstone Grit and Carboniferous Limestone that exists in parts of South Wales and Monmouthshire is clearly displayed. The exposure was first examined at the suggestion of the brilliant worker who threw so much light on Lower Carboniferous problems, the late Dr. Vaughan. The writer had explained[1] the attenuation of the Carboniferous Limestone Series in the Newport (Mon.) district as due to unconformable overstep by the Millstone Grit, similar to

[1] In "The Country around Newport" (*Mem. Geol. Surv.*), ed. 2, 1909, p. 20.

an overstep at this horizon that had already been observed near Haverfordwest, at the other end of the South Wales basin, by Professor O. T. Jones.[1] The value of the Ifton section in demonstrating that this overstep was widespread was recognized, and photographs, two of which are here reproduced, were secured by H.M. Geological Survey. Since then the unconformity at the eastern end of the South Wales coalfield has been confirmed by the detailed examination of a large area by Mr. F. Dixey and Dr. T. F. Sibly,[2] and has been found by the writer, in the course of work not yet published, to reach its greatest known extent in the Abergavenny district. Nevertheless, it seems desirable to describe the Ifton section because it is the clearest exposure known, in the whole of the South-West Province, of the unconformity between the Carboniferous Limestone and the Millstone Grit, and also on account of the remarkable inter-relations of the two formations which it reveals.

It should be observed that though the Ifton limestone-outcrop is continuous with that surrounding the Forest of Dean coalfield, the sandstones spoken of as "Millstone Grit" in the two areas, which are widely discontinuous, differ completely from one another in age and character. Those of the Forest of Dean have been shown by Dr. Vaughan[3] and by Dr. Sibly[4] to be Upper Avonian, the lower portion being correlated definitely by the latter worker with the upper Seminula subzone (S_2); he therefore justly separates the sandstones of the Forest of Dean from other "Millstone Grit" under the name of Drybrook Sandstone.

The Millstone Grit of Ifton cannot be placed palæontologically within narrow limits, but lithologically it resembles the Basal Grit of South Wales, which is the horizon also of the beds resting unconformably on the Carboniferous Limestone at Haverfordwest.

There is reason to believe[5] that the Basal Grit is correlative with part of the Pendleside Series. When it is remembered that other rocks of the South-West Province included in the Millstone Grit are certainly later than all Avonian and Pendleside zones—though they may not be Middle Coal Measures as suggested by R. H. Goode[6]—it can be seen how necessary it is to distinguish between the different components of the barren series, separating Limestone from Coal Measures, which has been given the useful name of Millstone Grit.

The areal extent of the unconformity remains to be determined. The break exists at the eastern and western ends of the North Crop of the South Wales basin, but is presumably absent at those intermediate places along the outcrop where radiolarian cherts are

[1] In "The Country around Haverfordwest" (*Mem. Geol. Surv.*), 1914, p. 151.
[2] *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1918, p. 111.
[3] *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, pp. 251–2.
[4] Geol. Mag., 1912, p. 417; Geol. Mag., 1918, p. 25.
[5] E. Dixon, "The Country around Pembroke and Tenby" (*Mem. Geol. Surv.*), 1921, chap. x.
[6] *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 272, 275.

developed at the base of the Millstone Grit. In Gower and South Pembrokeshire the junction is almost certainly conformable.

Description of the Ifton Section.

The exposures at Ifton, which lie 5½ miles south-west of Chepstow, are disused parts of a quarry north-west of the junction of the roads from Caerwent and Magor. The formations present in the quarry are:—

3. *Trias.*—Brown, buff, or red friable sandrock and loose sand, up to 6 feet in thickness, the lowest few inches littered with angular fragments, chiefly of Carboniferous Limestone, Millstone Grit and impure limonite. They rest on an even platform eroded across Limestone and Grit alike, and doubtless represent a sandstone that forms the base of the Keuper Marl in this district, resting immediately on the Dolomitic Conglomerate where the latter is present.

2. *Millstone Grit.*—Hard sandstone, partly quartzitic and occasionally somewhat pebbly, with soft shales weathering to clay, both rocks raddled by ferruginous waters, the shales to purplish tones. The few moulds of plant-fragments present are generally small and indeterminable, but a large stem,[1] found *in situ*, has been identified by Dr. Kidston as a Carboniferous type, probably a *Lepidophloios*. The beds fill steep-sided channels and underground cavities, eroded in the Carboniferous Limestone, in the manner to be described later.

1. *Carboniferous Limestone.*—Limestones, chiefly oolites or amorphous-looking calcite-mudstones, with some "subsequent" (vein-) dolomite; in colour white, light-grey, or various red tones owing to raddling. All the beds appear to be free from *contemporaneously-deposited* sand. The fossils, of which *Seminula ficoides* Vaughan is the most abundant, and the rock-types show that they belong to the Seminula Zone, a conclusion to which Dr. Vaughan had come prior to my visit. The Dibunophyllum Zone, which in its normal development is characterised by distinctive fauna and rock-types, is certainly not represented by any part of the limestone.

The relations of the formations are illustrated by Pl. II (*a* and *b*) and Figs. 1 and 2; the general structure shown by Pl. II (*b*), the photographs for which and for Plate II (*a*) were taken in 1909, may still be seen in the quarry.

In Pl. II (*a*) a single Grit-filled channel in the limestone is cut across, practically at right angles to its trend, by the quarry-face; it is 22 feet deep from the base of the Trias, which rests at both sides on the enclosing limestone, to the bottom (marked by a hammer). The dark material above the broken white line is the Trias; its base, though somewhat uneven, crosses from limestone to Grit without any indication of post-Triassic subsidence. The sides of the channel are shown by a continuous white line. The lower two-thirds of the infilling is fine sandstone, in which bedding-planes are obscure except for some along the bottom, parallel to the broad base of the channel. The sandstone is hard, and unbroken by any subsidence since its consolidation. That its filling the channel dates from the Carboniferous is shown by its containing (at the point

[1] In the Geol. Surv. Coll. at Jermyn Street Museum (Regd. No. E.D. 1791).

marked with a black cross) the large stem of *Lepidophloios*? previously mentioned, the leaf-cushions impressing sandstone similar to, and continuous with, the rest of the rock. In the upper third, the thin sandstones and shales have a steady catenary bedding.

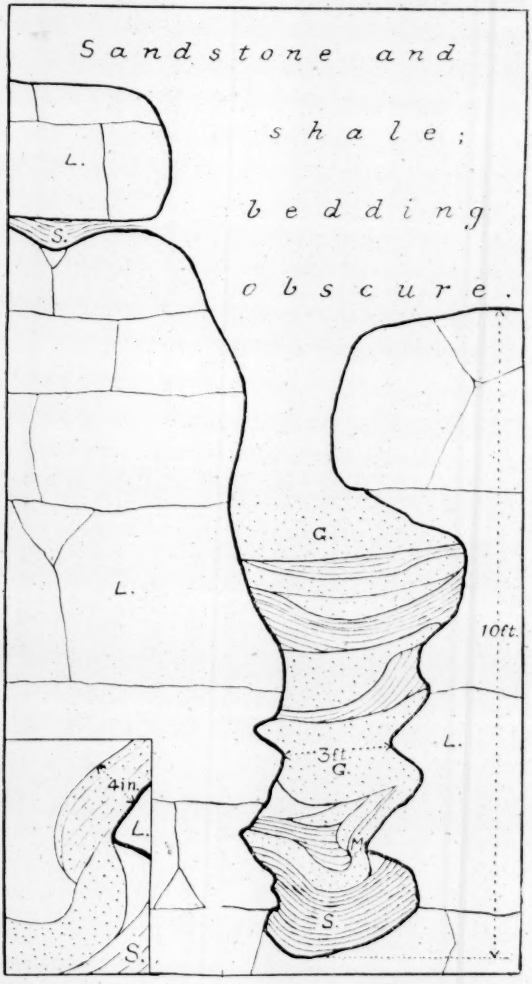


FIG. 1.—Diagrammatic sketch of a "pipe" in Carboniferous Limestone (L.), filled with sandstones (G.) and shales (S.). (Inset: detail of lamination in sandstone at M.)

The sides of the channel overhang in places, to a marked extent between the figure and the pick. The surrounding limestone, which occurs as almost horizontal beds—a well-marked layer runs along

below the hammer—contains cavities filled with sandstone, or with sandstone and shale. The latter are similar to, but generally smaller than, that shown in Fig. 2. One near the shovel has been partly picked out with a white line, but the others do not contrast sufficiently with the enclosing limestone to show up in the photograph. Those filled with sandstone alone are difficult enough to delimit on the ground, as the sandstone has a calcareous cement and is firmly welded to the similarly-weathering limestone that encloses it.

Pl. II (*b*) shows a wider extent of the junction of limestone and Grit, the distance from *A* to *E* being 50–60 yards. The base of the Trias (above and to the left of *B*) is shown by a broken black line. The surface of separation of Grit from limestone is marked, by continuous black lines, only where it is clear in the photograph; between the Grit-filled hollows *C* and *E* it was too complicated to be traced readily. For one thing undisturbed limestone has an awkward trick of poking up amid Grit where least expected. The masses in this position may be presumed to be remnants, isolated laterally by confluent Grit-filled hollows, somewhat similar to the top (*B*) of the limestone between the Grit-filled hollows *A* and *C*, which appears to be surrounded by Grit. Doubtless *B* is, or has been, continuous with the limestone below, and the strip of Grit, apparently below it, is either banked against it or fills a channel crossing it. In some cases, however, as in that of undisturbed limestone at *D*, the boundary with the Grit is most irregular, and no adjacent limestone is exposed.

Conversely, as in the limestone enclosing the channel shown in Pl. I (*a*), Grit appears repeatedly in the limestone below the black line, filling vertical "pipes" and irregular cavities. Generally the communicating passage with the main mass of Grit above is not to be seen, but one definite "pipe", shown in Fig. 1, is continuous therewith. The overlying Grit is seen on the right, and the bottom of the "pipe" is 10 feet below. The contents (sandstone and shale) have evidently remained undisturbed since their first introduction, as sand and mud, and consolidation. The 4 in. sandstone, shown in detail at the bottom of the figure, curves sharply in conformity with the steeply-sloping surface of the limestone-wall and with the shale filling the bottom of the "pipe", but is now quite hard.

A large, irregular cavity (Fig. 2), 6 yards in length, filled with sandstone and shale, of which the form was more than usually clear, was seen in the quarry-face opposite that shown in Pl. II (*b*). The sandstone occurs partly as a horizontal wedge, about 6 feet thick at the larger end, partly as thin laminæ interbedded with the shales. At one place small carbon-lined moulds suggest that plant-fragments have been washed in with the sand, now represented by the sandstone. On the right the cavity is prolonged vertically downward as a funnel-shaped shale-filled "pipe". This was cleared for 3½ feet below the sandstone-wedge without being bottomed.

The chief questions that arise are:—

1. Were the hollows in the limestone formed before or after the deposition of the beds spoken of as Millstone Grit?

2. What is the age of the so-called Millstone Grit?

1. The catenary bedding of the sandstones shown in Pl. II (*a*) suggests at first sight subsidence into a local hollow formed after their deposition. The remainder of the evidence is, however, overwhelmingly against this conclusion. The sandstones have been deposited as sand in their present position, and have not been disturbed since consolidation. They contrast strongly with the debris of Millstone Grit filling swallow-holes, both recent and pre-Glacial, in the Carboniferous Limestone at various places in South

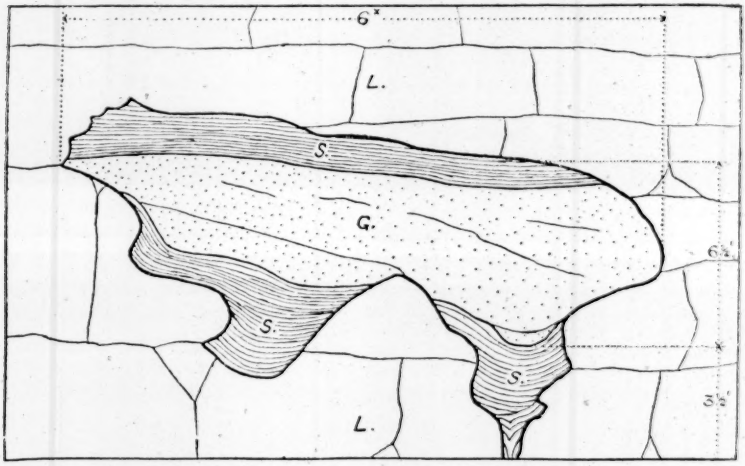


FIG. 2.—Diagrammatic sketch of a cavity in Carboniferous Limestone (L.), filled with sandstone (G.) and shales (S.).

Wales; in these the sandstones and shales are broken, or even thoroughly shattered, and jumbled together. The evidence that the Ifton sandstones have not been disturbed since consolidation needs to be unearthed in the field to be fully appreciated. It consists partly in the unbroken character of the hard beds, straight and curved alike, which are too brittle to bend, partly in the fact that the wedge-like form of some and the minor details of the lamination of others (as at *M*, Fig. 1) have been obviously determined by adjacent limestone-surfaces, and partly in the firm welding of some to the enclosing limestone.

2. The *Lepidophloios* ? was certainly deposited contemporaneously with the enclosing sandstone and was not part of a derived fragment. But this genus merely shows that the beds are Carboniferous. The lithological and stratigraphical evidence, however, is fairly conclusive. The choice of horizon lies between some part of the

Upper Avonian, the Basal Grit of the Millstone Grit, and some part of the Coal Measures.

As previously mentioned sandstones are present to a greater or less extent in the Upper Avonian in the adjacent Bristol and Forest of Dean districts, and in the eastern part of the South Wales basin also. But these sandstones are invariably conformable with the underlying beds, and cannot, therefore, be compared with the Ifton sandstones.

It is harder to choose between the Basal Grit and the Coal Measures. Both formations have been proved to rest unconformably on the Carboniferous Limestone in adjacent regions: in the South Wales basin, about 14 miles to the west, in the case of the Basal Grit; and in the Forest of Dean,[1] at the same distance to the north-east, in that of the Coal Measures. It is probable, too, that the unconformities on both horizons have been preceded by "piping" of the Carboniferous Limestone. This has certainly happened prior to the deposition of the Basal Grit, and appears also, from Dr. Sibly's [2] description, to have preceded the formation of the Coal Measures of the Forest of Dean.

In support of a Coal Measure age we have the presence of Coal Measures close by, Pennant Sandstone and coals having been proved[3] in the Severn Tunnel near Southbrook, 2½ miles east of Ifton. On the other hand, the Ifton sandstones resemble neither the Pennant, nor the Trenchard Upper Coal Measures, described by Sibly, that form the base of the Coal Measures in much of the Forest of Dean. It is possible, of course, that what have been spoken of as two unconformities are really but one, accompanied by persistent overlap of the overlying basal beds between South Wales and the Forest of Dean. On this hypothesis the Forest of Dean would represent part of the margin of the South Wales basin, and the Ifton sandstones might be correlative with neither the Basal Grit, deposited, presumably soon after the uplift and subsequent subsidence, in the interior part of the basin, nor with the Upper Coal Measures, laid down much later in the Forest of Dean. Simplicity has its charms, and the postulation of breaks in "conformable" series should be regarded as an unpleasant duty rather than a light mental exercise. But in this case it happens that a break between Middle and higher Coal Measures has been proved in Wyre Forest at no great distance north of the Forest of Dean. The hypothesis of a persistent overlap between South Wales and the Forest of Dean therefore does not help us. As a fact the Ifton sandstones so closely resemble the Basal Grit of South Wales that, in default of conclusive evidence to the contrary, we must refer them to that horizon and suppose, as a corollary, that there has been no overlap

[1] T. F. Sibly, Geol. Mag., 1912, p. 420.

[2] Geol. Mag., 1918, p. 26.

[3] Charles Richardson, *Proc. Bristol Nat. Soc.*, ser. III, vol. v, 1887, p. 49, section.

among the beds that have immediately overlain the Carboniferous Limestone for at least a dozen miles east of the main outcrop in South Wales. A determination of the age of the Coal Measures at the Severn Tunnel, which are exposed, so far as known, only in the half-tide rock called Lady Bench, would be both interesting and important; their relationship to the so-called Millstone Grit that was proved below in the Tunnel works we cannot hope to learn. This Millstone Grit appears, from the descriptions and section made by the first engineer [1] of the tunnel and by one of his assistants,[2] to have "piped" the underlying Carboniferous Limestone as do the Ifton sandstones.

A minor point is the question whether any of the Grit now present in Ifton quarry has been deposited in the light of day or whether it has all been laid down in cavities, the limestone-roof of which has been removed by the pre-Triassic denudation. The fact that some of the channels, such as that in Pl. II (*a*) and *A* in Pl. II (*b*), which, from their relative positions in the quarry, are probably continuous one with the other, are *large and widen upward* may count for little, but the persistence of the Grit beneath the Trias for a distance of 50 yards, more or less at right angles to the trend of these channels, suggests deposition in the open.

Conclusions

The Carboniferous Limestone was eroded subærially prior to the deposition of the Ifton sandstones, the Dibunophyllum Zone presumably being removed and the Seminula Zone below irregularly worn into deep channels with steep, even overhanging sides, into vertical "pipes" descending an unknown depth into the limestone, and into every conceivable intermediate form of cavern and passage.

The sandstones and shales, with rare plant-remains, that were then deposited in and on the limestone were contemporaneous with the Basal Millstone Grit.

My cordial thanks are due to the Ifton Limestone Company, Ltd., for their courtesy in readily permitting me to examine the quarry and to publish this account, to the Director of H.M. Geological Survey for the photographs for the plates, and to Messrs. T. C. Hall and G. Maunsell for help in the field.

[1] Charles Richardson, *op. cit.*

[2] E. D. Jones, *Proc. Geol. Assoc.*, vol. vii, 1881–2, p. 339.

Correlation between the Meadfoot Beds of Devonshire and the Siegenian of the Ardennes (Lower Devonian).

By Etienne Asselberghs, D.-en-Sc. (Louvain), of the Geological Survey of Belgium.

Sect. 1.

In a study of the Lower Devonian of the "Bassin de l'Eifel"[1] the present writer established the following sequence in the Siegenian Beds (= Siegenerstufe of the Rhine) of the southern part of the Ardennes:—

Upper Siegenian or Hunsrückian.	Upper: dark blue shales and slates. Lower: quartzophyllades, often calcareous (lenticular limestone of Bouillon), sandstones, and shales. Very fossiliferous.
Lower Siegenian or Taunusian.	Dark blue slates and shales interbedded with quartzite.

The Lower Hunsrückian has yielded an important fauna,[2] and the most characteristic species are: *Proschizophoria* [*Orthis*] *personata* (Zeiler) Kayser *em.*, *Stropheodonta Murchisoni* Archiac and Verneuil, *S. Sedgwicki* A. and V., *S. gigas* McCoy, *S. herculea* Drevermann, *Schuchertella ingens* Drevermann, *Spirifer hystericus* Schlotheim, *S. excavatus* Kayser, *S. primaevus* Steininger, *S. solitarius* Krantz, *Rhynchonella papilio* Krantz, *R. Dannenbergi* Kayser, *Rhenorensselaeria crassicosta* Koch, *R. strigiceps* Roemer, *Uncinulus frontecostatus* Drevermann, *Cornellites Paillettei* Verneuil and Barrande, *Grammysia taunica* Kayser, and *Cryphaeus Drevermanni* Richter.

The purpose of this note is to show that the same succession occurs in Cornwall and South Devonshire.

Sect. 2.

The Lower Devonian of Cornwall is a quartzoschistose complex affected by numerous plications and dislocated by a great number of faults. Therefore the geologists who tried to establish a stratigraphical succession met with difficulties far exceeding those experienced by workers in the Ardennes. Nevertheless, they distinguished three formations known, in descending order, as the Staddon Grits, the Meadfoot Beds, and the Dartmouth Slates.

The Dartmouth Slates correspond to the Gedinnian of the Ardennes. On the other hand, the Staddon Grits are succeeded by

[1] Le Dévonien inférieur du Bassin de l'Eifel et de l'Anticlinal de Givonne dans la Région sud-est de l'Ardenne Belge. Aperçu général sur le Bassin de l'Eifel entre la Meuse et la Kyll. *Mém. Inst. géol. de l'Université de Louvain*, vol. i, 1913, pp. 1–175, pls. i–iii.

[2] The fauna of this horizon of the southern border of the Bassin de Dinant has been made known by Béclard (*Bull. Soc. belge de Géol.*, vol. i, 1887, pp. 60–96) and by Maillieux (ibid., vol. xxiv, 1910, *Mém.*, pp. 189–220). I have given a critical list of the species collected in the Bassin de l'Eifel (loc. cit., pp. 85–132). This list has been added to by Maillieux (*Bull. Soc. belge de Géol.*, vol. xxviii, 1914, *Proc. verb.*, pp. 77–9).

shales and limestones with *Calceola sandalina* Lamarck. It follows, therefore, that the Meadfoot Beds and the Staddon Grits are the equivalent of the Siegenian, Emsian, and the beds with *Spirifer cultrijugatus* Roemer. The correlation therefore stands thus :—

Ardennes and Rhine.	South Devonshire.
Couvinian : Shales and limestones with *Calceola sandalina*.	
Beds with *Spirifer cultrijugatus* / Emsian or Coblenzschichten / Siegenian or Siegenerstufe.	Staddon Grits and Meadfoot Beds.
Gedinnian (Upper).	Dartmouth Slates.

The comparative study of the Devonian Beds of the two countries has been left in this summary state. I will try to go a little further by recalling what is known concerning the Meadfoot Group.

Sect. 3.

Ussher[1] has shown that the Meadfoot Group of Cornwall can be divided into three horizons, of which the two oldest have been traced throughout the county and also in Torbay. The following is the succession of strata in descending order :—

c. Grey slates with occasional beds and seams of grit (thick beds of grit are seen near Plymouth).
b. Very fossiliferous shales, slates and grits; calcareous bands with corals and crinoids (lenticular limestones).
a. Dark grey slates with hard grit and quartzite beds.

The middle horizon is easily recognizable by its calcareous bands and fossiliferous beds—the latter have yielded a very rich fauna—and can be traced through the numerous folds.

The first fossils were found at Looe and were described by Davidson.[2] E. Kayser has drawn attention to the affinities of this fauna with that of the Taunusquartzit of the Rhine.[3] More recently Drevermann showed that the fossils of Looe exist in the Siegenerstufe of Seifen.[4] In 1915 I had the opportunity of seeing the fossils from Looe in the British Museum (Natural History), and I was impressed by the great affinities of the fauna of Looe with that of the Lower Hunsrückian of the Bassin de l'Eifel. All the brachiopods from Looe occur in the Ardennes. The following table gives Davidson's list, beside my identifications :—

Athyris sp. ? pl. iv, fig. 4.	*Athyris avirostris* Krantz.
Spirifera primaeva Steininger ? ? pl. viii, figs. 1–3.	*Spirifer primaevus* Steininger.
Spirifera sp. ? pl. iv, fig. 33.	*Athyris avirostris* Krantz.
Spiriferina cristata var. *octoplicata* ? pl. vi, figs. 11–13.	*Spirifer excavatus* Kayser.

[1] *Mem. Geol. Surv. England and Wales* : Explanation of Sheet 350 (1903), 348 (1907), 347 (1909), 349 (1912). *Proc. Geol. Assoc.*, vol. xx, 1907, pp. 78–93. "Geology in the Field" : *Jubilee Vol. Geol. Assoc.*, 1910, pp. 859, et seq.

[2] Davidson, "A Monograph of the British Fossil Brachiopoda" : vol. iii, pp. 126–7. *Mem. Pal. Soc.*, 1864–71.

[3] *Jahrb. der. k. Preuss. Geol. Land.*, 1882, pp. 128–31.

[4] *Palaeontographica*, vol. iv, 1904, pp. 229–88.

Atrypa reticularis Linné.	
Rhynchonella Pengelliana Davidson, pl. xii, figs. 8, 9.	*Rhynchonella papilio* Krantz.
Rhynchonella sp.	
Streptorhynchus gigas McCoy.	
Pl. xvi, figs. 2, 3.	*Strophcodonta gigas* McCoy.
fig. 4.	*Orthothetes ingens* Drevermann.
Streptorhynchus vel *Leptaena* sp.? (*Leptaena* ? *Looiensis* Davidson), pl. xviii, figs. 13, 14.	*Strophcodonta Sedgwicki* Archiac and Verneuil.
Orthis (vel *Leptaena*) *laticosta* Conrad.	
Orthis hipparionyx Vanuxem ?	
Pl. xvii, fig. 8, 9, 12.	*Proschizophoria personata* (Zeiler).
fig. 10.	*P. provulvaria* ? Maurer.
fig. 11.	*Athyris avirostris* Krantz.

Later, other fossiliferous localities were discovered. Several lists of fossils have been published, but a great number of the identifications, based only on the already old descriptions of Phillips and Davidson, are doubtful. Thus, for instance, in the same list we find *Spirifer speciosus* and *S. primaevus* recorded together.[1] The identifications which seem to have been made with most care are those of Green[2] (1904–1906). From his lists we can add the following species to the above table: *Dalmanella circularis*, *Proschizophoria provulvaria*, *Strophcodonta Murchisoni*, *Leptostrophia explanata*, *Rhenorensselaeria strigiceps*, *Camarotoechia daleidensis*, *Spirifer hystericus*, and *Phacops Ferdinandi*. All these species are found in the Ardennes. Corals and crinoids are abundant. From this list we may conclude that the fauna of the fossiliferous horizon of the Meadfoot Group and that of the Lower Hunsrückian of the Ardennes are identical.[3]

Moreover, the fossiliferous beds of Devonshire consist of quartzoschistose rocks and sometimes calcareous rocks just as in the Ardennes, and they lie between two schistose horizons, of which the older contains intercalations of sandstone and quartzite. The same succession occurs in the Ardennes. Finally, both the Meadfoot Beds and the Siegenian rest on the purple and green shales of the Upper Gedinnian.[4]

[1] Hamling, Geol. Mag., 1909, pp. 133–4.

[2] Geol. Mag., 1904, p. 406; 1906, pp. 34–5.

[3] This opinion has been confirmed by a recent rapid examination of the specimens from Looe and Fowey in the Sedgwick Museum, Cambridge, and the Geological Survey Collection at Jermyn Street, London.

[4] This is not quite true of the western part of the Bassin de l'Eifel, where the formations are much thicker. There exist between the red and green shales of the Gedinnian and the shales and quartzite of the Taunusian, two horizons: one consists of greenish shales (Schistes de St. Hubert) and the other of quartzophyllades and shales (Lower Taunusian). These two horizons disappear towards the east and in the neighbourhood of Laroche, at the south-western corner of the "Massif de Stavelot", the red and green shales of the Gedinnian are succeeded immediately by the slates and quartzites of the Taunusian.

I therefore propose the following correlation :—

Meadfoot Group.	Siegenian.
c. Grey slates with bands, and locally thick beds, of grit.	*c. Hunsrückien supérieur*: phyllades bleu foncé de Neufchateau (intercalations gréseuses dans le Grand Duché de Luxembourg).
b. Fossiliferous beds of Looe: slates and grits, calcareous shales, and lenticular masses of dark-grey limestone.	*b. Hunsrückien inférieur*: quartzophyllades fossilifères, souvent calcareux ; lentilles calcarieuses de Bouillon.
a. Dark grey slates with hard grit and quartzite beds.	*a. Taunusien* : phyllades bleu foncé avec intercalations de grès quartzite gris bleuâtre.

Sect. 4.

It follows logically from the above correlation that the Staddon Grits, which lie between the beds with *Calceola sandalina* and the Meadfoot Beds, correspond to the Emsian Group and the *Cultrijugatus* Beds of the Ardennes.

The stratigraphical succession in the Staddon Grits is not known in detail as yet, but I do not doubt that the principal fossiliferous horizons which characterize these beds in the Ardennes will be found in Devonshire by detailed research. These horizons are, in ascending order, the beds with *Spirifer hercyniae* and *Tropidoleptus rhenanus*, the beds with *Sp. arduennensis* and the beds with *Sp. cultrijugatus*. In fact, some localities in the neighbourhood of Torquay have already yielded *Tropidoleptus rhenanus*; others *Sp. cultrijugatus*.[1]

From the foregoing remarks the correlation of the Lower Devonian and the Lower Middle Devonian of South Devonshire and the South of the Ardennes stands thus :—

South of Devonshire.		Ardennes and Rhine.	
Limestones and slates with *Calceola sandalina*.		Assise à *Calceola sandalina*	Couvinien.
Staddon Grits.		Assise à *Sp. cultrijugatus*	Emsien ou Coblenzstufe.
		Assise à *Sp. arduennensis*	
		Assise à *Sp. hercyniae* et *Tropidoleptus rhenanus*	
Meadfoot Beds.	Grey slates.	Hunsrückien supérieur	Siegenien ou Siegenerstufe.
	Fossiliferous Looe Beds.	Hunsrückien inférieur	
	Slates with quartzite.	Taunusien	
Dartmouth Slates.		Schistes bigarrés du Gedinnien.	

In the correlation table given by Dr. J. W. Evans in 1917,[2] it will be noticed that the Staddon Grits are made to correspond with the

[1] Ussher, "The Geology of the Country around Torquay" (Explanation of Sheet 350) : *Mem. Geol. Surv.*, 1903.

[2] Evans, "Devonian (Sedimentary Rocks) of Great Britain" : *Handb. d. Regionale Geol.*, vol. iii, pt. i ; *The British Isles*, 1917, pp. 134–5.

Cultrijugatus Beds and the Meadfoot Group with the Emsian and Siegenian. I am unable to find any evidence in favour of this parallelism in the detailed studies of Mr. W. A. E. Ussher on the Devonshire rocks. On the contrary, it seems foolish to correlate the whole of the Staddon Grits with the *Cultrijugatus* Beds, when certain bands of the former have yielded *Tropidoleptus rhenanus*.

SECT. 5.

Finally, a few words may be said about the Devonian rocks of North Devon. The stratigraphical succession is less known than in the South; nevertheless, it seems very doubtful if it will ever be possible to distinguish the three horizons of the Siegenian in the Lynton Beds which correspond to the Meadfoot Beds, according to Ussher[1] and Evans.[2] In fact, the Devonian of North Devon, where the quartzoschistose facies characterizes not only the Lower Devonian but affects also the Lower Middle Devonian (Couvinian) and even the lowest beds of the Givetian, would have to be compared with the Northern border of the "Bassin de Dinant" or with the "Massif de la Vesdre". In the latter region the Devonian rocks below the Givetian Limestone consist of an alternation of purple-red shales and greenish arenaceous bands; conglomerates occur at several horizons.[3] More especially the Siegenian consists in the upper part of purple-red shales and greywacke with pink sandstones, and in the lower part of grey and bluish sandstones and quartzites with dark-blue slates. *Haliserites Dechenianus* and bone-beds of Ostracoderms (*Pteraspis*) are frequent in the Taunusian or Lower Siegenian.[4] In the same way the Lynton Beds of Devon contain beds with *Pteraspis*. In the present state of our knowledge, however, it is not possible to establish a more detailed correlation between the Lower Devonian of North Devon and the Ardennes.

SECT. 6.

In 1912 I showed that the Siegenian presents the same succession in the South of the Ardennes—southern border of the Bassin de Dinant, Anticlinal de Bastogne, Bassin de Houffalize, Bassin de l'Eifel, Anticlinal de Givonne—and in the Siegerland. It may now be concluded that a similar succession occurs also in Cornwall and South Devonshire.

[*Note*: In accordance with modern usage Dr. Asselberghs adopts Siegenian and Emsian in place of the much misused term Coblentzian. The necessity for discarding the latter is shown by Maillieux, *Bull. Soc. belge de Géol.*, vol. xxx, 1920.—L. D. Stamp.]

[1] Ussher, "Geology in the Field": *Jubilee Vol. Geol. Assoc.*, 1910, pp. 864, et seq.

[2] Evans, GEOL. MAG., 1919, pp. 547–9.

[3] A section through the Massif de la Vesdre has been given recently in the *Bull. Soc. belge de Géol.*, vol. xxix, 1919, pp. 220–31.

[4] Asselberghs, "Découverte de bone-beds à Ostracodermes dans le Taunusien, à l'est de la Meuse": *Bull. Soc. belge de Géol.*, vol. xxx, 1920.

The Marginal Features of a Basic Dyke at Peldar Tor, Charnwood Forest.

By W. Alfred Richardson, M.Sc., B.Sc.(Eng.), F.G.S.

IN the most westerly working of Peldar Tor Quarry, in the north-west district of Charnwood Forest, a basic dyke is intruded into the porphyroid. Professor T. G. Bonney [1] briefly described the dyke in 1915. The intrusion shows a remarkable laminated margin, and the present paper is chiefly directed to a consideration of this feature.

I. Chemical Composition.

The Porphyroid.—T. G. Bonney and E. Hill determined this rock as a dacite. In Table I are collected all available analyses, and to these I have added another from a specimen chosen as typical of the rock in the neighbourhood of the dyke.

It will be seen that these analyses differ somewhat. This is doubtless due to variation of the specimens selected as regards quartz phenocrysts. For, while the rock exposed in the quarries is uniform when considered as a whole, yet the crowding of the quartz phenocrysts may fluctuate in different specimens. The analysis No. I from the Peldar Tor Quarry probably represents a specimen rather poorer in quartz than the general body of the rock, and the analyses Nos. II to IV are more typical.

TABLE No. I.

	I	II	III	IV
SiO_2	61·28	65·14	67·96	66·32
Al_2O_3	16·11	16·13	14·87	13·69
Fe_2O_3	7·22	5·37	10·60	8·54
MgO	4·19	2·19	1·10	2·09
CaO	6·33	5·16	1·69	2·59
Na_2O	0·99	1·56	5·07 }	4·50
K_2O	3·84	1·75	tr. }	
P_2O_5	——	——	tr.	0·75
MnO	tr.	——	tr.	n.d.
Ignition	——	2·14	——	2·05
Total	99·96	99·44	101·29	100·53

I. "Porphyroide," Peldar Tor Quarry, Whitwick (by the courtesy of Mr. J. H. Robinson).

II. Do., Forest Rock Quarry, Whitwick (by the courtesy of Mr. J. W. Berrington).

III. Do., Peldar Tor (T. G. Bonney, *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 199; analyst, E. Berry).

IV. Do., Peldar Tor Quarry, most westerly sinking near Greenstone Dyke.

A comparison of these analyses with the mean given by Daly [2] indicates that for dacites they are high in iron and low in alkalies.

[1] Bonney, Geol. Mag., 1915, p. 548.

[2] Daly, *Igneous Rocks*, New York, 1914, p. 25.

Nor do they show very close agreement with respect to those constituents with any individual dacite, the analysis of which is available. The rock would seem to be a rather basic member of the group. There is, however, a tonalite from Lake Avio, Tyrol,[1] whose analysis compares much more closely with that of the porphyroid.

The Dyke.—The dyke shows a chilled marginal phase and a crystalline centre. I give in Table II analyses from the best obtainable specimens of each phase. It will be seen that they represent, as Professor Bonney suggested, a dolerite. The analysis from the centre compares with the quartz dolerite of the Whin Sill, quoted in column III.

TABLE No. II.

	I	II	III
SiO_2	52·21	50·43	51·22
Al_2O_3	16·09	14·44	14·06
Fe_2O_3	13·00	12·80	4·32
FeO	n.d.	n.d.	8·73
MgO	4·15	4·35	4·42
CaO	5·44	11·12	8·33
Na_2O	3·09	1·04	1·25
K_2O			2·55
P_2O_5	0·40	0·45	—
MnO	n.d.	n.d.	—
TiO_2	n.d.	n.d.	2·42
Ignition, etc.	5·00	5·00	2·37
Total	99·38	99·63	99·67
Sp. Gr.	2·77	2·81	

I. Greenstone Dyke, Peldar Tor Quarry, Whitwick. Marginal Phase.
II. " " " " Centre.
III. Quartz Dolerite, Whin Sill, Cauldron Snout. (J. J. H. Teall.)

It will be noticed that the marginal phase is rather more acid and of lower specific gravity than the centre of the intrusion. This may possibly be due to a slight amount of marginal assimilation, for microscopic slices at the contacts show portions of the porphyroid partially absorbed. The specimen analysed was obtained quite close to one of the contacts.

II. Petrography.

The Porphyroid.—Little need be said about this rock, since it has been minutely described by Professor Bonney.[2] The phenocrysts consist of corroded and fractured quartz, plagioclase, and aggregates of fine epidote grains, forming pseudomorphs after a ferromagnesian mineral. One of these preserves an almost perfect octagonal cross-section with prism faces nearly at right angles, indicating that the

[1] Iddings, *Igneous Rocks*, vol. ii, New York, 1913, p. 142, No. 2.
[2] Bonney & Hill, *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 342, 1880.

original mineral was pyroxene. The groundmass contains a second generation of felspars, rather more acid than the phenocrysts, but is otherwise largely cryptocrystalline.

The Greenstone.—Under the microscope a specimen from the dyke centre is seen to be holocrystalline and of medium grain. It is completely altered. With the exception of quartz none of the original minerals remain. The rock now consists mainly of quartz, chlorite, kaolinized pseudomorphs after felspar, calcite, and iron oxide. The structure is best made out by reflected light, when felted patches of lath-shaped felspars are seen to be surrounded by dark chlorite, showing that the original structure was ophitic or sub-ophitic.

The chlorite is in ragged crystals and forms a kind of groundmass to the slide. It shows strong pleochroism and numerous inclusions of magnetite, and has the velvet-brown ultra-interference tints of penninite.

The felspar pseudomorphs are chiefly kaolin, sometimes with a grain or so of epidote here and there; but calcite replacements are not uncommon.

The iron-ores are all changed to hæmatite and sometimes to leucoxene.

Quartz is the most interesting mineral. There is a good deal more of it than the analyses would lead one to expect. Little triangular fragments, similar to those seen in the Whin Sill, are clearly interstitial. Others take on the shape of felspar laths, and show a central plane of division corresponding to a Carlsbad twin-plane. The two halves extinguish differently. These larger quartz crystals may include calcite and chlorite flakes. Much of this quartz is doubtless secondary. Strain shadows are shown, but not so marked as in the quartz of the porphyroid.

In one slide only there occur some irregularly oval rings of magnetite, enclosing carbonates very suggestive of pseudomorphs after olivine. The occurrence of these pseudomorphs is another reason for considering that the quantity of original quartz was probably small.

It would thus seem certain that the rock forming the centre of the dyke was originally an ophitic dolerite, and possibly a quartz-dolerite.

The marginal phase is very fine-grained. Many of the specimens obtainable are badly weathered and reveal little under the microscope. The dyke has again been quarried more recently and better marginal material has been made available. A slice cut from one of these specimens contains minute felspar laths, the larger of which are simply twinned. They appear to be oligoclase. The groundmass has a general greenish tinge and is cryptocrystalline. It is quite indeterminate, and was doubtless originally glassy.

The Contact.—Slides cut at the junction show that the contact is marked by a film of iron oxide, *aa*, Fig. 1

The dyke-rock *b* has the characteristics already described for the marginal phase, but the felspar laths show fluxion arrangement parallel to the line of contact.

The porphyroid at the contact has in hand-specimens quite a different appearance to the normal rock. In colour it is generally lighter, greenish, and blotchy. The normal dark-coloured rock can, however, be found attached to fresher portions of the dyke. I think that Professor Bonney is correct in considering these colour variations in the porphyroid as due to weathering, for here the two rocks have often parted along the contact line, and so afforded a passage for water.

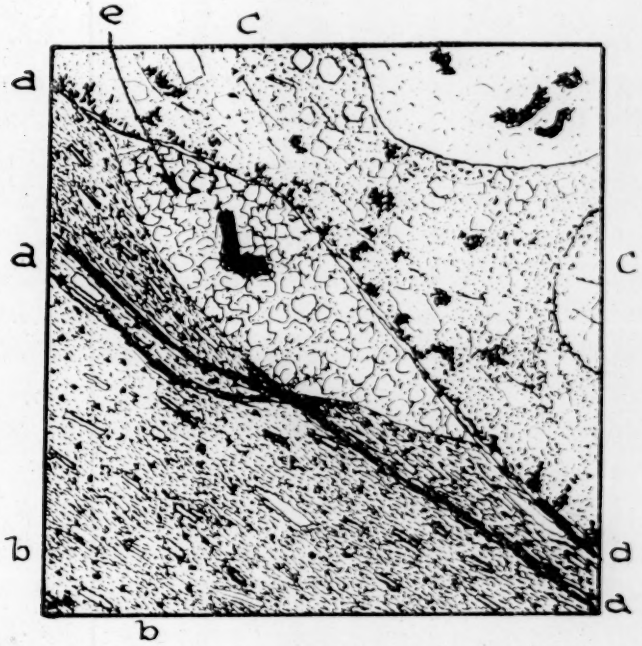


FIG. 1.—Junction of Peldar Tor porphyroid (*c*) and dolerite dyke (*b*). × 54.

Under the microscope the porphyroid, *c*, Fig. 1, has the same general appearance as in the normal rock. There is, however, a marked absence both of traces of ferromagnesian minerals and epidote. Instead there is a large amount of indeterminate green material in the groundmass. The felspars are sometimes distinctly resorbed, and the groundmass near the contact has recrystallized. It then consists of rounded grains of what I take to be felspar set in a felted network of the greenish material already mentioned. Small lenticular patches, *e*, Fig. 1, of clear recrystallized material are caught up along the line of contact, and suggest a certain amount of marginal assimilation by the dyke. Along the contact line in one

slide there is a green mineral, with the refractive index and pleochroism of hornblende, but a low extinction. More exact determination is difficult, for there are only two or three small pieces all similarly orientated. Whether this is the product of contact metamorphism, or is developed by the crushing of the mass, is difficult to say.

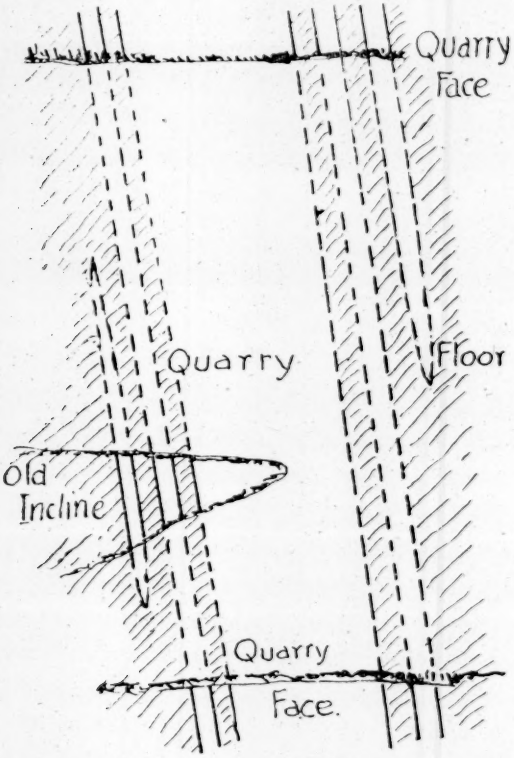


FIG. 2.—Diagrammatic plan of quarry floor showing the form of the laminated marginal sheets. Hatched portion = porphyroid, blank = dolerite dyke.

III. FIELD RELATIONS.

The most interesting features of the dyke are to be found in the field. The dyke trends W.N.W. and hades to the east at about 5 degrees. Its width varies somewhat, but is nowhere less than 12 feet.

Professor Bonney thinks that it has suffered more than the porphyroid from shearing. Specimens from the margin do cleave much more readily than the latter rock, but this is doubtless due in part to the fluxion banding already mentioned. The dyke at the

centre is much less affected than the margin by cleavage, and its quartz in thin section has no very prominent strain phenomena.

The most remarkable feature is the presence of laminated margins (Fig 3). They occur at both sides of the dyke. At first sight they resemble columnar basalt, or certain shearing effects. They really

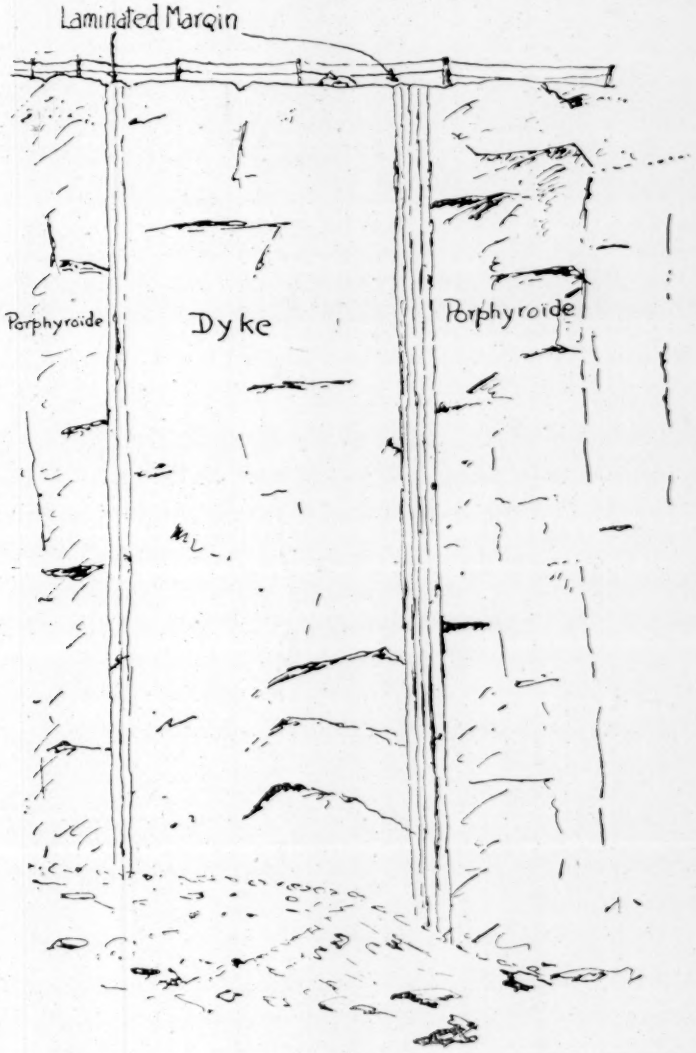


FIG. 3.—Peldar Tor Quarry. Exposure of dolerite dyke showing marginal lamination. View looking north.

consist of alternating sheets of country rock and dyke. These sheets are each about 9 inches thick, and vary in number from two to four. The dyke material of these sheets is chilled, and this chilled phase also extends not less than 2 feet from the main dyke margin.

It was not found practicable to trace the dyke across the floor of the quarry. In 1914, however, an old tramway incline, since quarried away, exposed a portion of the dyke, and was situated between the two exposures on the quarry face. By means of this exposure the reconstruction of the course of the dyke across the floor given in Fig. 2 was made. This sketch is not drawn to scale, and the marginal features are exaggerated in size to show their character. It will be seen that the sheets of dyke material fill cracks of lenticular cross-section in the wall. These cracks die out and may be replaced by others along the course of the dyke.

To the north the dyke cannot be traced, but it does not enter the Trias. Although nothing can be seen of it at present, it has been followed for a short distance southwards.

IV. The Age of the Dyke.

The dyke, as just mentioned, does not enter the Keuper marl, and is therefore pre-Triassic.

Although in composition and probable mineralogical character it strongly resembles certain Carboniferous dolerites (a few of which are to be found in Midland Coal-measures), it is much more altered than the Carboniferous intrusions. Moreover, it has shared the cleavage of the surrounding rocks, and must be considered as belonging to the pre-Cambrian suite. It should be noted, however, that the well-developed chilled marginal phase points to the country rock being quite cold at the time of the dyke intrusion.

V. The Origin of the Marginal Lamination.

The dyke occurs to the west of the main Charnian anticlinal axis, and has the hade and direction of the chief faults of the district. There is no evidence of movement, and the included sheets of porphyroid show no signs of shearing or brecciation.

There are three possible explanations of the phenomenon.

1. Contraction of the dyke on consolidation may have cracked the sides and provided means of further intrusion. It would seem that several successive contractions were necessary each of the same order of magnitude, and this does not seem reasonable. Moreover, as in the case of certain "multiple" dykes, it might be expected that the junction of the dyke and the country rock would provide the readiest line of fracture.

2. The other cracks may have been formed by a renewal of tension at a later time. Here, again, one would expect the line of junction to be the most likely plane of weakness. Examination in the field and of the slices at the margin suggests, moreover, that the intrusion and consolidation of all the dyke material took place concurrently.

3. Several tension cracks may have opened at one time. During a long experience in testing various kinds of materials by slowly loading them in tension, I only remember two cases where the test piece gave way at more than one surface. Both cases were very brittle cast-iron. On the other hand, if a piece of material in tension be subjected also to a sudden blow, it is very liable to go at more than one plane. This is seen in the sudden tearing of cloth, where in addition to the main tear, several of lenticular shape and parallel to the main tear frequently appear. If the intrusion occurred at a time of anticlinal tension and the molten material below subjected the crust above to a sudden impulse, the rupture, instead of being confined to one plane, would oscillate over a small region, finally causing fracture at a number of closely spaced vertical planes. The main mass of magma rushed up one of these fissures, and at the same time a smaller amount filled the adjoining cracks. The uniform width of the sheets and the length over which they are exposed suggests suddenness of action, for if the process had been prolonged the main dyke might have been expected to transgress from one fissure to another in different parts of its course.

This explanation is of interest in the light of J. Barrell's theory, based on thermodynamic grounds, that dyke injection has often proceeded in a violent and explosive manner.[1]

The Contaminated Gabbro of Easter Saphook near Old Meldrum in Aberdeenshire.

By H. H. Read, H.M. Geological Survey, Scotland.

Introduction.

In North-East Scotland the igneous rocks have been divided into two series, whose times of intrusion were separated by the movements responsible for the foliation and disposition of the crystalline schists of that area.[2] With the older series, intruded prior to or during those movements, this paper is not concerned. The younger, or non-foliated, series supplies rock types ranging from peridotite to granite. Gabbro is the chief rock in the large independent basic masses formed by the younger igneous rocks; to the more important of these masses may be given the names of the Huntly, Insch, Boganloch, Haddo, Arnage, Maud, and Belhelvie Masses. For the most part they lie within Sheets 76, 77, 86, and 87 of the 1 inch Geological Survey Map of Scotland.

This paper is concerned with a group of rocks which can be shown to result from the incorporation of sedimentary material in the gabbro magma. Chief amongst the rocks resulting from the mixture

[1] J. Barrell, U.S.A. Geol. Surv., Prof. Paper, No. 57, p. 157, 1907.

[2] H. H. Read, *Summary of Progress for 1918*, 1919, p. 24. Geol. Mag., Vol. LVII, 1919, p. 364. *Summary of Progress for 1919*, 1920, p. 23.

is cordierite-norite, but other mixed rock types, of unquestionably similar origin, occur very abundantly in Aberdeenshire and the general group name of *Contaminated Gabbro* has been provisionally adopted for rocks resulting from a gabbro magma contaminated with sedimentary material.

Before 1914 two occurrences of contaminated gabbro had been described, one in France, the other in Minnesota. In 1898–9 an account of the cordierite-norites of Le Pallet, Loire-Inférieure, was given by Lacroix.[1] In 1900 A. N. Winchell [2] published the results of a very detailed mineralogical and petrographic study of cordierite-norite, quartz-gabbro, and orthoclase-gabbro from Minnesota. Both authors held admixture with sedimentary material to be the cause of these modifications of the normal gabbro magma.

In 1914 W. R. Watt [3] described cordierite-norites and associated rocks from Wells Cuternach, near the farm of Drumdelgie, 3 miles west-north-west of Huntly, Aberdeenshire. He said :—

"It appears certain that the rocks of this (Cuternach) type originated from a magma contaminated by the aluminous material of the phyllites.

"It is greatly to be regretted that no clear sections exist to prove in the Huntly occurrence a gradual transition from undoubted igneous rock to undoubted phyllite" (loc. cit. p. 288).

In 1919 the localities of this type of cordierite-norite were vastly increased, contaminated norites being shown to occur over great parts of the Huntly Mass.[4] Moreover, sections were discovered which showed that there could be no doubt that the formation of cordierite-norites and allied contaminated rocks was due to the incorporation of sedimentary material in the gabbro magma.

A year later the distribution of contaminated gabbros was again widened by their discovery as a marginal modification of the hypersthene-gabbro of the independent Insch Mass near the farm of Easter Saphook, $2\frac{1}{2}$ miles west by north of Old Meldrum.[5] During this year (1920) in an investigation of the igneous rocks of the Arnage Mass, undertaken during leave from official work, I have found that contaminated norites bulk very much larger than the uncontaminated nuclear norite. It may be said, then, that contaminated gabbros occur, so far as is known at present, in the Huntly, Insch, and Arnage Masses, and there is every possibility that their distribution will be still greater as the remaining younger igneous masses of North-East Scotland come to be studied.

[1] A. Lacroix, "Le Gabbro du Pallet et Ses Modifications": *Bull. Carte Geol. de la France*, vol. x, 1898–9, pp. 341–96.

[2] A. N. Winchell, "Mineralogical and Petrographic Study of the Gabbroid Rocks of Minnesota, etc.": *American Geologist*, vol. xxvi, 1900, p. 294 et seq.

[3] W. R. Watt, "Geology of Country around Huntly (Aberdeenshire)": Q.J.G.S., vol. lxx, 1914, pp. 266–93.

[4] H. H. Read, *Summary of Progress for 1918*, 1919, pp. 29, 30.

[5] H. H. Read, *Summary of Progress for 1919*, 1920, p. 26.

Contaminated Gabbros of Easter Saphook.

Easter Saphook is situated at the extreme end of the Insch Mass, some 2½ miles west by north from Old Meldrum. The contaminated gabbros outcrop in several small knolls around the copse a few hundred yards south of the farm. Small quarries opened in these knolls provide excellent specimens of the mixed rocks. Just east of this locality various types of sedimentary gneisses are seen near the burn which runs from north to south a few hundred yards east of Easter Saphook. The mixed rocks, therefore, occur at the margin of the igneous mass.

The uncontaminated igneous rock of this part of the Insch Mass is a fairly uniform hypersthene-gabbro.[1] It is a fine-grained greyish rock, weathering into rectangular slabs. In thin slice the texture is seen to be uniformly equigranular. The constituent minerals are labradorite, hypersthene, augite, and magnetite. The felspar occurs in stout crystals. The two pyroxenes are about equal in amount and are often intergrown. The hypersthene builds vividly pleochroic prismatic grains; the augite forms similarly shaped grains with a well-marked diallagic parting.

Around Easter Saphook, however, the uniformity which elsewhere characterizes the hypersthene-gabbro is lost. Here the rocks become very variable, all degrees of textural and mineralogical variations being seen in the same exposure and often in the same hand-specimen. Hornfelsed sedimentary blocks can be hammered out of the contaminated igneous matrix. It is at once apparent that here are assimilation phenomena similar to those repeatedly observed in the Huntly Mass.

At Easter Saphook the earliest stage in contamination is represented by a hypersthene-gabbro, which, whilst in the main similar to the normal rock of that group, yet shows peculiar features, indicative of its mixed origin. These least modified types are medium-grained greenish rocks, with little of that variability shown by more modified examples of this suite. Their constituent minerals are labradorite, hypersthene, scarcer augite, biotite, quartz, magnetite, and secondary green hornblende. Evidences of modification are provided by:—

(i) The presence and skeletal arrangement of the biotite, which is always near iron-oxide grains.

(ii) The occurrence of scattered areas of quartz, which often forms patches, blebs, and points in the felspar, and then the two minerals tend to occur in regular granophyric or micropegmatitic intergrowths.

(iii) The purplish grey appearance of the hypersthene.[2]

(iv) The tendency of the hypersthene to form a collection of grains rather than homogeneous crystal plates. There is a rude orientation of felspar and hypersthene, pointing to movement during consolidation.

[1] Ibid., p. 24.
[2] W. R. Watt, loc. cit., pp. 282, 286.

Further stages show increasing divergence from the igneous rock until the main characters of the mixture become dependent more upon the sedimentary than upon the igneous components. This divergence is exemplified firstly by a group containing much quartz, and secondly by a group containing cordierite.

In the first branch the components are andesine, quartz, hypersthene, biotite, garnet, magnetite, and zircon. Chlorite and hornblende are of late secondary formation. The felspar forms euhedral crystals; quartz is abundant; hypersthene commonly occurs in small grains vividly pleochroic in red, yellow, and blue-green tints. Yellow to red biotite builds large plates usually with the skeletal form characteristic of this group of rocks; garnet occurs associated with biotite and magnetite.

A further stage along this line of divergence is possibly provided by a rock which has felspar, quartz, and biotite as its main constituents. The turbid zoned felspar varies from oligoclase to andesine; the biotite is yellow to black and forms ragged plates; quartz is common. Prisms of dark bluish-green tourmaline are noteworthy. This mixed rock is very like the Kennethmont quartz-diorite [1] in its quartz, biotite, and felspar, but lacks the green hornblende of the true quartz-diorite. It is, of course, possible that the original igneous rocks of Saphook had as a member a rock already somewhat differentiated from the main gabbro type before contamination had occurred. Such a possibility, whilst by no means to be neglected, is rendered less likely by our experience of the very variable contaminated rocks of the Huntly Mass.

The second line of divergence from the normal hypersthene-gabbro is characterized by a very variable group containing cordierite. At Saphook it is impossible yet to trace that detailed destruction of hypersthene and the formation of biotite, cordierite, garnet, etc., so well seen in the Huntly Mass. The Saphook cordierite-bearing rocks are nearer the sedimentary than the igneous end of the series.

A member of this cordierite-bearing group is a rock made up in hand-specimen of black biotite plates and pinkish felspar in streaky, almost gneissose, association. In thin slice, the biotite builds large yellow to brown-black plates, usually ragged and often showing the skeletal or rudimentary forms characteristic of this suite. Cordierite is abundant in small grains, and shows magnificent pleochroic haloes and common sector-twinning. Amongst the felspars are found microcline, orthoclase, and andesine. Sillimanite forms fibrous needles in the cordierite and stouter blades in the biotite; greenish spinel and clots of magnetite complete the slice. An allied type is composed of quartz in patches and grains, abundant cordierite in large, slightly pinitized grains, pink garnet, yellow-red ragged biotite, and grains of andesine and magnetite. These abnormal rocks show

[1] H. H. Read, *Summary of Progress for 1919*, 1920, p. 25.

the great modification that the gabbro magma can undergo by the incorporation of sedimentary material.

It may be useful to combine these observations into the following statement of mineral composition :—

Hypersthene-gabbro : Labradorite, hypersthene, augite, magnetite.

Contaminated gabbros : Labradorite, hypersthene, augite, magnetite, together with biotite, quartz, orthoclase, microcline, andesine, garnet, tourmaline, cordierite, sillimanite, spinel.

Results from the Huntly Mass.

The Huntly Mass [1] of younger igneous rocks is about 16 miles from north to south, with an average breadth of 3 miles in an east and west direction. At many localities in this large area, contaminated gabbros are now known. Watt [2] originally described them from Wells Cuternach. I have found them extremely well developed at the following independent localities : (1) near Ward ; (2) Battlehill Quarry ; (3) Castle Bridge, Huntly ; (4) Hill of Kinnoir ; (5) Rivestone ; (5) a great spread of about 1 square mile around Cuttlehill ; (7) Fowlwood ; (8) Barry Hill ; (9) Wether Hill. The last three localities are in Banffshire. Most, but not all, of these localities are at the margin of the igneous mass. Here the contaminated gabbros form the matrix between lumps of partly digested hornfels ; the digestion may sometimes proceed so far that a fairly homogeneous contaminated gabbro results.

Watt gave an excellent description of the Wells Cuternach rocks, together with an analysis in which it was shown that over 50 per cent of the rock was composed of cordierite. He distinguished two stages of contamination : first, the formation of cordierite-norites, and finally the formation of garnet-labradorite-biotite rock.

The Cuternach locality presents several points of difficulty. The neighbouring igneous rock is a so-called picrite,[3] which may be taken to form the basal part of the composite intrusion of the Huntly Mass. Between the picrite and the schists to the west, appear the Cuternach cordierite-norites. Three views may be taken of these relative positions.

(1) The basal picrite has been modified by the incorporation of sediment to produce cordierite-norite.

(2) Or there was an original norite intruded between the picrite and the sediments to the west to provide the igneous magma for the contaminated norite.

(3) Or the contamination of the original gabbro magma of the

[1] H. H. Read, *Summary of Progress for 1918*, 1919, pp. 28, 29.
[2] W. R. Watt, loc. cit.
[3] W. R. Watt, loc. cit., p. 274. H. H. Read, *Summary of Progress for 1918*, 1919, p. 28.

whole Huntly Mass took place along its base before an ultrabasic bottom layer had time to collect.

It must be admitted that of these three possibilities the last is the most attractive, and would be readily adopted if one was sure that *any* kind of differentiation in place had occurred in the Huntly Mass.[1] On this point extremely conflicting evidence may be found if the whole of the mass is considered. As Watt remarked, it is unfortunate that these rocks of Cuternach occur in cultivated ground. No advantage can be obtained at present by dogmatic statements.

The remainder of the occurrences of contaminated norites are fortunately free from doubt. The original purely igneous rock is the great norite [2] of the Huntly Mass. This fine-grained bluish rock consists of ophitic, granular, or granitic associations of bytownite (Watt), hypersthene, augite, olivine, hornblende, biotite, magnetite, apatite, and zircon.

A summary of the study of the contaminated norites may be given. These rocks are extremely variable in texture and composition, and contain partly digested hornfels chunks. The minerals observed in the contaminated norites are :—

Cordierite, garnet, hypersthene, labradorite, andesine, orthoclase, biotite, spinel, sillimanite, magnetite, quartz, rutile, zircon.

This assemblage is like that already given for the Saphook contaminated gabbros. In the field, in hand specimen, and in slice, the contaminated gabbros of both the Huntly and Insch Masses are thoroughly alike.

Foreign Occurrences of Contaminated Gabbros.

Professor Lacroix [3] described the occurrence in the quarry of Les Prinaux at Le Pallet, Loire Inférieure, of xenoliths of mica-schist surrounded by a layer of cordierite-norite separating them from normal olivine-gabbro. Lacroix deduced that *both norite and cordierite-norite* had resulted from the incorporation of sedimentary material of suitable composition in the olivine-gabbro magma. At present I am not prepared to admit a similar origin for the norites of North-East Scotland. I am, however, in entire agreement with Lacroix as to the origin of the cordierite-norites, and have extended the group of contaminated gabbros to include many diverse kinds of assimilation rocks.

A. N. Winchell [4] described the occurrence of cordierite-biotite-norites (" muscovadytes ") along the contact of gabbro and schist in Minnesota ; such contaminated gabbros are confined to the contact zone. Winchell considered the cordierite-norites to result from the absorption of aluminous material from the surrounding

[1] See H. H. Read, Geol. Mag., Vol. LXX, 1919, p. 370.

[2] W. R. Watt, loc. cit., p. 272. H. H. Read, *Summary of Progress for 1918*, 1919, p. 28.

[3] A. Lacroix, loc. cit.

[4] A. N. Winchell, loc. cit.

sediments. He also discussed the formation of quartz-gabbro and orthoclase-gabbro and concluded (loc. cit. p. 365) that the following modifications of the gabbro magma by sedimentary contamination had taken place :—

(1) Digestion of aluminous sediment : cordierite-norite.

(2) Digestion of siliceous schists or quartzite : quartz-gabbro.

(3) Digestion of potassic rock : orthoclase-gabbro.

From the field relations and mineral composition it is apparent that the contaminated gabbros of Huntly and Saphook are of similar origin to those of Le Pallet and Minnesota. The following tabular statement exemplifies the close resemblance between the four occurrences :—

Saphook.	*Huntly.*	*Le Pallet.*	*Minnesota.*
Labradorite. Andesine.	Labradorite. Andesine.	— Acid andesine.	Labradorite. Andesine (rare).
Orthoclase. Microcline.	Orthoclase. —	— —	— —
Hypersthene.	Hypersthene.	Hypersthene.	Bronzite-enstatite
Biotite.	Biotite.	Biotite.	—
Cordierite with haloes.	Cordierite with haloes.	Cordierite with haloes.	Cordierite without haloes.
Garnet.	Garnet.	Almandine.	No garnet.
Quartz.	Quartz.	Quartz.	Quartz.
—	—	Staurolite?	Staurolite.
—	—	Graphite.	Graphite.
Spinel rare.	Spinel common.	Spinel common.	Spinel rare.
Sillimanite.	Sillimanite.	Sillimanite.	No sillimanite.

Conclusions.

In North-East Scotland there is a great development of gabbros contaminated with sedimentary material. By the incorporation of this sedimentary material in the gabbro magma rocks are produced in general of abnormal composition and characterized by minerals not proper to gabbro and often not proper to any purely igneous rocks. Sometimes, however, there may be produced a rock of undoubted assimilation origin, but which in mineral content approaches a purely igneous rock, though not a gabbro. The further exploration of the contaminated igneous rocks of North-east Scotland may, therefore, perhaps throw some light upon current theories of differentiation.

REVIEWS.

LE PLATINE ET LES GÎTES PLATINIFÈRES DE L'OURAL ET DU MONDE. By LOUIS DUPARC and MARGUERITE N. TIKONOWITCH. Quarto, pp. vi + 542, with xi plates and atlas. Geneva: 1920.

PROFESSOR DUPARC'S researches in the Urals began in 1900 with an examination of the platinum deposits of the Koswinsky district, and have been extended until they include the central mountain-belt from 53½ degrees to 61½ degrees latitude. Important memoirs on certain districts have already appeared, besides numerous smaller contributions, chiefly petrographical, by the Professor and his coadjutors in the laboratory at Geneva. The work now before us presents in final shape the results of the whole investigation; while its scope has been further extended to include more briefly the other platinum-producing countries of the world, besides a number of technical matters.

The Ural chain is folded towards the west, and forms part of the Hercynian orographic system, though there is evidence of earlier movements on the same lines. In the axis of the chain appear crystalline schists, which are invaded by a great profusion of igneous rocks, mainly basic and ultrabasic, and it is to these intrusive rocks that the geological interest chiefly attaches. Of first importance are the dunites, which form oval masses with their long axes parallel to the mountain-chain. Each of the several occurrences exhibits the same relations, being bordered by a zone of pyroxenites, and again by an outer zone of gabbros and allied types. The main body so constituted is further traversed by numerous dykes, presenting a wide range of variety. Four chapters are devoted to the detailed petrography of these rocks; the dunite and allied peridotites; the pyroxenites and koswites, a group of rocks composed of olivine, augite, hornblende, chrome-spinel, and interstitial magnetite; the gabbros and their allies, including the tilaites, in which pyroxene is strongly preponderant over felspar, and often imparts a pseudo-porphyritic character; and finally the dyke-rocks, which embrace a great variety of types. Since many of these rocks have already been described, they do not call for particular notice here; but we may mention in passing the "plagiaplites" with primary brecciation, which afford strong ground for the belief that the uralitization of pyroxenes may be a magmatic process.

It has long been established on circumstantial evidence that the platinum found as grains in river-gravels and sands is derived from ultrabasic plutonic rocks; but so sparsely is it distributed in its primary situation, that only by prolonged search has such occurrence been verified. Our authors are able to prove directly that platinum is a normal constituent in very small amount of the dunites and pyroxenites of the Urals. In the former it is found either as small

grains idiomorphic against the olivine, or, more usually, in segregations of chromite. When platinum is present in the pyroxenites, it occurs interstitially as the latest product of crystallization.

It is well known that platinum never presents itself in nature as a pure metal, but always in alloy with other members of the "platinum group" and with iron. In the material studied, from the Urals and elsewhere, the authors distinguish among the constituents of the various mixtures five groups: iridium, osmides of iridium, palladium, platinum, and iron. The native iridium is rare, but "osmides of iridium", often in rhombohedral crystals, form part of most of the crude platinum of the Urals. The term employed seems to imply the existence of definite compounds, and indeed two types are discriminated and named, but the chemical analyses show much variation. Palladium is extremely rare in the Urals, though often present in the South American platinums. The Russian native platinum, unlike the Brazilian, contains iron as its most important element after platinum, and two types are recognized: polyxene, with 6 to 10 per cent of iron, and ferroplatinum, with 12 to 20 per cent, the latter being magnetic and of dark colour. The chemistry of the platinum group of metals is not without difficulties for the analyst. A discussion is here given of the various laboratory methods, and a large number of analyses are brought together.

Since exploitation of platinum in its original home is manifestly out of the question, it is the more important to study the alluvial deposits from which it is actually procured. The authors find that the present distribution of the platinum is not always in accord with the existing drainage of the country. In the case of the Koswa river-system, that which is now found in the tributary streams has been derived from older deposits, laid down when the river flowed at a higher level and followed a different course. A full description is given of the methods practised in prospecting and working platiniferous deposits. Then follows a detailed description of the numerous occurrences in the Urals, with more summary notices of those of Ronda in Spain, El Choco in Colombia, Brazil, British Columbia, Borneo, and other countries. The last three chapters deal with the metallurgical processes for treating the crude platinum, the various industrial uses of the metal, and statistics of production. We learn that in a period of 92 years the deposits of the Urals have produced 231,664 kilos (316·4 tons), exclusive of the large quantity lost every year by theft. In 1911 Russia furnished more than 93 per cent of the world's supply, Colombia ranking second with 6 per cent. Further exploration of the northern Urals, and especially of little known Colombia, may possibly lead to an enlarged output in the future, but it is certain that platinum can never be other than a rare metal.

Embodying a large amount of original research and summarizing practically all that is known at the present date, this will doubtless

long remain the standard authority on a subject which possesses great geological interest and economic importance. Throughout it is clearly written and liberally illustrated. The Atlas contains a general map of the region and detailed geological maps of the four most important districts, together with a series of plates illustrative of technological processes.

A. Harker.

The Coral Reef Problem and the Evidence of the Funafuti Borings. By E. W. Skeats. Amer. Journ. Sci., vol. xlv, 1918. pp. 81–90.

In this paper the author, who is highly qualified for the task, reviews the evidence afforded by the study of the material from the Funafuti bores in the light of recent developments in the study of coral-reefs, with special reference to the work of Daly and Davis. Incidentally, he makes the interesting statement that the experts who examined this material were not allowed to express in their reports any opinions as to the mode of formation of the atoll, but he believes he is correct in saying that they were unanimous in the conclusion that their results supported Darwin's theory of subsidence, and, in fact, were fairly susceptible of no other known explanation.

Three points specially dealt with in this paper are the submarine profile of Funafuti, Daly's and von Lendenfeld's views and diagrams of the development of atolls, and the mechanism of the filling of "lagoon moats". It is shown that all the core-material consists of shallow water organisms, mostly in the position of growth. No trace of deep-water organisms was found in any part of the core down to 1,114 feet, and no stratification was detected such as is inevitable in a talus deposit.

The filling of the so-called "lagoon moat" is shown to be due mainly to growth of *Halimeda* and other organisms, sediment playing but a subsidiary part, and it is noted that measurements have shown that some lagoons are becoming shallower, which effectively disposes of Murray's solution theory

The general conclusion reached from this revision of the evidence is that the only cause capable of accounting for all the facts is subsidence. This is in exact accord with the opinion expressed by Professor Sollas in 1905, in a couple of notable essays on the results of the Funafuti expeditions.

CORRESPONDENCE.

A NATURAL "EOLITH" FACTORY BENEATH THE THANET SAND.

SIR,—A paper by Mr. H. Warren has been published recently by the Geological Society (*Q.J.G.S.*, vol. lxxv, part 3, No. 303, January, 1921), entitled "A Natural 'Eolith' Factory beneath the Thanet Sand", which, in view of the erroneous statements it contains, I ask permission to criticize in the pages of the GEOLOGICAL MAGAZINE.[1] Mr. Warren describes a certain series of naturally fractured flints found in the Eocene Bullhead Bed at Grays in Essex, and proceeds to compare these specimens with others—regarded by most archæologists as humanly fashioned—found under totally different conditions in various parts of this country. To those who take an interest in pre-historic archæology, the occurrence and nature of these pressure-fractured Eocene flints, such as Mr. Warren discusses, have been known for years past. In 1910 M. l'Abbé H. Breuil published in *l'Anthropologie* (t. xxi, 1910, pp. 385–408) a detailed account of a large series of specimens—similar to those found at Grays—discovered by him at Belle Assise in France, while in 1914 I was able to describe the flaked and broken flints which I had found in the Bullhead Bed at Coe's Pit, Bramford, near Ipswich (*Proc. Prehis. Soc. of E. Anglia*, vol. i, part 4, pp. 397–404).

It is not my intention to reopen the discussion upon the characteristics of these typical examples of flints broken by natural pressure, nor again to point out the fundamental differences between them and those found by Mr. Harrison upon the plateau of Kent, and of others of different forms recorded from the sub-Crag detritus bed. I would merely ask those who may regard Mr. Warren's paper seriously to compare the drawings of the specimens found by him with those of the Kentian and sub-Crag implements which have been illustrated in the publications of various learned societies. Such a comparison will at once show the marked differences between these shattered and fragmentary Eocene specimens, and the two other classes of flaked flints mentioned. I may say that I saw the selected material exhibited by Mr. Warren when he read his paper before the Geological Society, and I do not hesitate to affirm, with a full knowledge of all the facts, that it is preposterous to claim that the Grays specimens have any real bearing upon the flints found by Mr. Harrison and by myself. And I am amazed at Mr. Warren's lack of caution in describing, in his paper, such fractured specimens as he has found as "Kentish and sub-Crag forms of chipping" and "Carinate sub-Crag forms of chipping". The publication of such statements makes it perfectly clear that he has no real knowledge of

[1] Those who wish to refer to my published opinions upon this question will find them set forth in *Science Progress*, No. 41, July, 1916, pp. 37–50.

the Kentian and sub-Crag implements. If a comparison is made of the drawings which illustrate the Abbé Breuil's paper, already mentioned, with those published by Mr. Warren, it will be seen that the two series portray specimens of a very similar character. Both papers describe and illustrate fractured flints of the haphazard kind, such as would be expected to be produced by some natural, non-human force, and it would be easily possible, by imitating Mr. Warren's methods, to claim that at Belle Assise and at Grays there exist "Natural 'Palæolith' Factories", and so to emulate the efforts of those who, in the past, refused to believe in the human origin of any pre-Neolithic flaked flint.

I notice that on p. 243 (paragraph 4) of his paper, Mr. Warren draws attention to one of the Eocene flints, in the following words: "A polished mark, associated with a series of V-shaped incipient fractures, indicates the passage of an intermittent jolting force. . . . Among these Bullhead flints such marks are usually lines of high polish, and not scratches. Upon exposure to atmospheric influences the crushed flint would weather out and leave a slight groove."

I have never yet seen a "V-shaped" incipient fracture such as is described above, nor do I believe that it exists, except in Mr. Warren's imagination. These incipient cones of percussion—for that is what they are—are caused by the point of the agent of striation passing over the surface of the flint subjected to the striating movement. They are more or less circular in form, but, in such a case as Mr. Warren describes, none are complete, and a series of half-circles (occurring in a line) very close to, and sometimes overlapping, each other is to be observed. This line indicates the path taken by the agent of striation, and the succession of contiguous semicircles is caused by the numerous blows administered by the unevenly travelling point of the agent of striation.[1]

In course of time small cracks appear to develop from the ends of and extend these incipient fractures (giving rise to what are sometimes known as "centipede markings", from their superficial resemblance in outline to the legs of this creature), and these extensions have, apparently, misled Mr. Warren, and have induced him to describe the incipient fractures upon his specimen as being definitely shaped like a V.

I am interested to see that he adopts the view, already published, as to the weathering out, under atmospheric influences, of such incipient fractures, but I notice that he omits to mention the original paper in which this matter was first made public. In case the suppositions contained in this paper should turn out, eventually, to be

[1] For a very complete and interesting description of analogous incipient fractures produced in the surface of glass by grinding and polishing the reader is referred to a paper entitled "More Notes on Glass-grinding and Polishing" by Mr. James Weir French (*Transactions of the Optical Society*, vol. xviii, January, 1917). In this paper Mr. French points out (p. 22) that the direction of the movement of the agent of striation was always found to be towards the *convex* side of the semicircular fractures.

incorrect, and Mr. Warren caused to bear a responsibility which there is no need for him to shoulder, I beg to state that the paper to which I refer will be found in *Science Progress*, No. 44, April, 1917, pp. 597–603. It is entitled "Scratches on Flints", and was written by me.

On p. 247 (paragraph 6) of Mr. Warren's paper a description is given of a large flake, the bulb of which is "cross-cut by the éraillure which was formerly supposed to be the exclusive character of the human blow". Who is the unfortunate person who has been responsible for making such a palpably absurd statement as this? Perhaps Mr. Warren can supply me with the needed information, but whoever made such a statement must be singularly devoid of even a rudimentary knowledge of flint fracture. Mr. Warren's paper is, in my judgment, not calculated to help towards the solution of the serious archæological problems it purports to discuss.

J. Reid Moir.

February 26, 1921.

THE GLACIATION OF IRELAND.

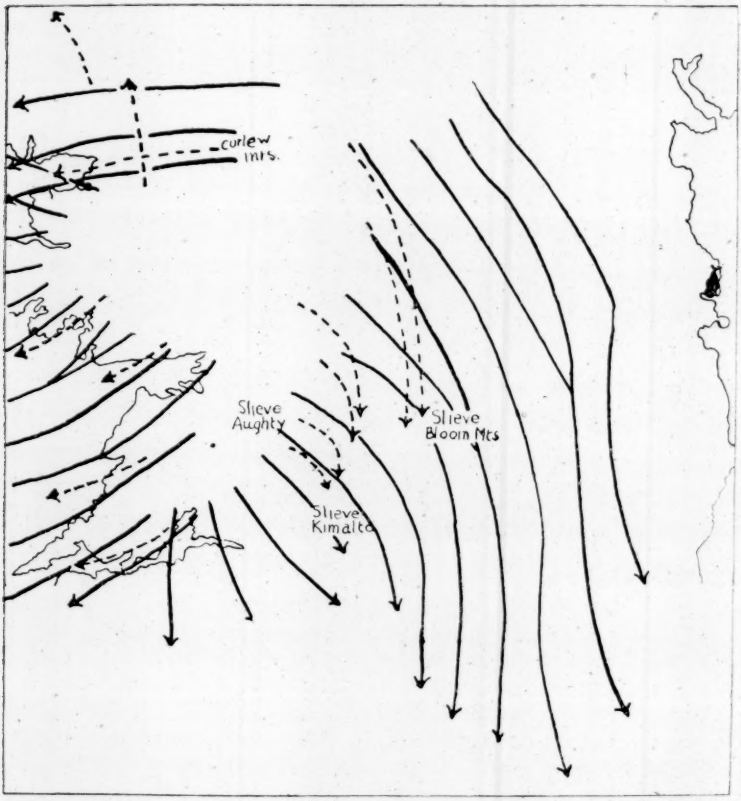
Sir,—I accept Professor Gregory's implied reproof of my habit of "regarding views that" I "do not accept as simple mistakes", and plead in mitigation of any penalty that my article in the February Geological Magazine is only the second time in twenty years that I have indulged in public controversy. I should be greatly interested if Professor Gregory would suggest any logical method by which I could indicate my dissent from opinions with which I disagree without regarding their author as mistaken.

As to the general subject of the glaciation of Ireland, I am perfectly content to leave such of your readers as are interested to compare my criticism with what Professor Gregory deems an adequate answer.

There is, however, one point which raises wider issues than those of Irish Geology. In answer to my observation that the Roscrea esker is not at the northern end of the mountains, but a few miles south-west of the southern end, he retorts that "They" (the Roscrea, Clonaslee, Mount Mellick, and Maryboro' eskers) "are part of one crescentic series around the northern end of the range. Moreover, the term Slieve Bloom Mountains is sometimes used (e.g. Phillips [*sic*] *Atlas of Comparative Geography*, and the map used in Carvell [meaning Carvill] Lewis' *Glac. Geol. Gt. B. and I.*, 1894, opp. p. 83) to include the geological continuation of the range south-west of the Roscrea Gap".

To make good this extended use of the name Professor Gregory does not appeal to his own map or to any authoritative map of Ireland, neither to Griffith's nor the beautiful layered maps of the Ordnance Survey, but to Carvill Lewis's little "track-chart" on the scale of 31·5 miles to 1 inch, in which—apparently to meet the exigencies of space—the lettering of "Slieve" begins about 5 miles south-west of Roscrea, and, actually, to a half-crown school atlas!

I now come to what strikes me as a matter of great gravity. In my previous communication I uttered a protest against a small portion of a map in W. B. Wright's *Quaternary Ice Age*, being enlarged up to the full breadth of a quarto page, and pointed out that the enlargement had been so badly done by the artist (a charitable assumption) that though the arrows indicating the ice-flow are stated to be "added from the map by Mr. Wright", some had been "swung round through angles of 20–40 degrees". Judge



of my surprise to learn that the whole work was deliberately done by Professor Gregory himself. He says: "Eleven out of the thirteen lines follow the originals precisely; the two easternmost are rather generalized to show the movement east of Lough Ree, and trend rather farther to the west than the nearest corresponding of Mr. Wright's lines."

May I be permitted again to use the obnoxious word "mistake"? Professor Gregory is mistaken, wholly mistaken, in supposing that only two of the lines were "rather generalized". Every

one of the lines in the Shannon Basin, making six in all, have been deflected, five of them considerably and one through an angle of 45 degrees, so as profoundly to modify the interpretation. The two "rather generalized" have been generalized to such effect that the arrow which should pass down the *east* side of the Slieve Bloom Mountains is carried down the *west*. The figure on p. 190 shows Wright's arrows by the full lines and Professor Gregory's version by broken lines. The superposition was done by photographic projections from a lantern slide in use here.

These may seem small matters, but it would strike at the very root of our confidence in scientific statement of fact if an author were permitted without protest to take any liberties he might choose with the work of another author and describe the result as "after W. B. Wright" or "added from the map of Mr. Wright".

PERCY F. KENDALL.

Leeds.

THE NOMENCLATURE OF PETROLOGY.

SIR,—Dr. Arthur Holmes, in his useful little book with the above title, disapproves of the term *syenoid*, which I have used as a contraction of felspathoid-syenite, giving as his reason that the suffix *-oid* has been used in other senses, as in granitoid, trachytoid, pegmatoid (Evans), and dacitoid (Lacroix). The matter is a very trivial one, but in the present involved condition of petrographic nomenclature no proposal for simplification should be dismissed without fair consideration, and the very examples that Dr. Holmes quotes show that he has not considered the matter fully. Of the four terms that he quotes, the last two are of later introduction than mine, so that I might at least claim the right of priority. This is true, too, of Lacroix's revival of "basanitoid"; and I cannot recall any other instance of a rock name in current use that ends in *-oid*. Then granitoid and trachytoid are adjectives, and should correctly be written granitoidal and trachytoidal, just like conchoidal and saccharoidal. But a more important consideration is just that *every* familiar suffix is used in various senses, and the ubiquitous *-ite*, for example, serves for rocks, minerals, fossils, meteorites, alloys, chemicals, official drugs, patent medicines, and a great variety of commercial products. I think, then, that Dr. Holmes' objection is not a very well-reasoned one.

The reason why it seems desirable to have a single word in place of the double-barrelled "felspathoid-syenite" is pretty obvious. In the first place these rocks are quite as distinct from the syenites as are—let us say—the monzonites, and they have therefore an equal claim to a distinctive name. In the second place, nepheline-syenite is long enough already, and when further mineralogical qualifications have to be added the name becomes unwieldy. A dreadful example of this is Dr. H. A. Brouwer's "ægirienamphiboolbiotietnepheliensyenietporphyr".